An Examination of Pre-Service Mathematics Teachers' Integration of Technology into Instructional Activities Using a Cognitive Demand Perspective and Levels of Technology Implementation

Ahmet Oguz Akcay

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AN EXAMINATION OF PRE-SERVICE MATHEMATICS TEACHERS’ INTEGRATION OF TECHNOLOGY INTO INSTRUCTIONAL ACTIVITIES USING A COGNITIVE DEMAND PERSPECTIVE AND LEVELS OF TECHNOLOGY IMPLEMENTATION

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By
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AN EXAMINATION OF PRE-SERVICE MATHEMATICS TEACHERS’ INTEGRATION OF TECHNOLOGY INTO INSTRUCTIONAL ACTIVITIES USING A COGNITIVE DEMAND PERSPECTIVE AND LEVELS OF TECHNOLOGY IMPLEMENTATION

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ABSTRACT

AN EXAMINATION OF PRE-SERVICE MATHEMATICS TEACHERS’ INTEGRATION OF TECHNOLOGY INTO INSTRUCTIONAL ACTIVITIES USING A COGNITIVE DEMAND PERSPECTIVE AND LEVELS OF TECHNOLOGY IMPLEMENTATION

By

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May 2016

Dissertation supervised by Dr. Melissa Boston

Technology has changed every aspect of our lives such as communication, shopping, games, business, and education. Technology has been used for decades in the teaching and learning environment in K-12 education and higher education, especially in mathematics education where the use of instructional technology has great potential. Today’s students have grown up in the technology era, so our education system should consider this situation before developing curriculum and instructional strategies. Technology can increase the quality of mathematical investigations, portray meaningful mathematical ideas to students and teachers from multiple perspectives, and change traditional ways of doing mathematics (NCTM, 2000). According to NCTM’s Principles and Standards for School Mathematics (2000), technologies not only increase students’ understanding and learning of mathematics but also help teachers make instruction more effective and meaningful for students.
The purpose of this study is to explore how pre-service teachers design mathematics lesson activities that integrate technology. Specifically, the level of cognitive demands of the mathematics tasks in the technology activities: 1) created by pre-service teachers (PST) for an assignment in their elementary, middle level, and/or secondary mathematics methods course, and 2) created and used by secondary mathematics PSTs during student teaching were examined.

PSTs designed technology-based instructional activities with high-level cognitive demands, and the mean scores were increased for Described Implementation and Student Response. In these instances, elementary and secondary level PSTs were able to select technology-based tasks with high cognitive demands in greater percentages than middle level PSTs. The mean scores for Described Implementation and Expected Student Response were higher than the means for Potential of the Task for all grade levels. However the means scores for Expected Student Response were lower than the means for Described Implementation for the elementary and middle levels, and the means scores are same for the secondary level. The results also indicated that PSTs were doing very well with their own personal computer use, troubleshooting, identification of instructional practices that reflected a learner-based curriculum design, and effectively technology implementation. By the analyzing relationship between IQA rubrics scores (Potential of the Task, Describe Implementation, and Expected Student Response) and each LoTi-Digital Age levels (PCU, CIP, and LoTi), the researcher discovered that the LoTi Digital-Age scores did not correlate with the IQA scores.
I would like to dedicate this dissertation to my wife, Sevinc Akcay, to my parents, Meryem and Hasan Akcay, and to other members of my family. Thank you for supporting me in every step of the way and your investment of so much of your time and energy allows me the opportunity to complete this degree. I am forever grateful for your love and support.
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CHAPTER I
INTRODUCTION

The world has changed extraordinarily because of new knowledge, new tools, and new technologies. Technology has changed every aspect of our lives such as communication, shopping, games, business, and education. Technology has been used for decades in the teaching and learning environment in K-12 education and higher education, especially in mathematics education where the use of instructional technology has great potential.

We live in a time that is both technologically and mathematically based. New technologies are developed based on mathematical knowledge (Kilpatrick, Swafford, Findell, & National Research Council, 2001); hence, people need to be able to understand and do mathematics to engage in opportunities to shape the future effectively (National Council of Teachers of Mathematics [NCTM], 2000). Today’s students cannot survive economically in the 21st century without technology supported learning opportunities, and traditional education that lacks instructional technology cannot provide these opportunities for students (International Society for Technology in Education, ISTE, 2000). The NCTM Principles and Standards for School Mathematics (2000) addresses six central principles for school mathematics, and technology is one of these principles. NCTM’s technology principle states, “technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning” (p. 24).

Teaching strategies and the school curricula have changed considerably during the past 40 years (Heddens & Speer, 2006). In mathematics and other subjects, today’s students are often bored during lessons delivered through direct instruction, because they only need to listen to the
lecture and sit at their chair during the class (Schrum & Levin, 2009). Today’s students have grown up in the technology era, so our education system should consider this situation before developing curriculum and instructional strategies. Twenty-first century students are different from previous generations. Described as digital natives, they can easily use and understand technology (Schrum & Levin, 2009). We need to teach students differently, because they learn and think differently from adults (e.g., teachers and school leaders), who are described as digital immigrants (Prensky, 2001; Schrum & Levin, 2009). The major differences between digital natives and digital immigrants are their comfort levels with technology and their ways of processing information and learning using technology (Cunningham, 2012; Zur & Zur, 2011). Compared to digital immigrants, digital natives access information very quickly and communicate with their peers effectively using technology (Cunningham, 2012).

Instructional technology has the capacity to help students to engage in mathematical activities; because of this, it affects the content of school mathematics (Heid & Blume, 2008). Instructional technologies are defined as 21st century or/digital age teaching tools, such as internet sources, tablet PCs, Interactive White Boards, graphing calculators, instructional software, mobile devices, and so on. Different technological tools can be used for different aims and benefits. Calculators and computers are electronic technologies, and they are investigated by teachers and used by students to teach, to learn, and to do mathematics (NCTM, 2000). A teacher might choose to “employ a particular process or a specific technology to increase the likelihood that a presentation addresses a specific learning style or intelligence” (Lever-Duffy, McDonald, & Mizell, 2003, p.23). For example, interactive whiteboards could be used by students to find slope in a graph and/or for display, or the internet could be used to provide simulations and also to find information fast. Heddens and Speer (2006) note that nowadays the technology in the
mathematics classroom is changing from calculators to computers. Focusing on what
technologies to use to support instruction, how to use them, and when to integrate them are
essential. Teachers should manage students’ use of instructional technology, such as software,
graphing calculators, computer, and dynamic geometry to ensure that the technology is
supporting students’ learning of mathematics.

Teachers can enhance mathematics instruction including, but not limited to, using
questioning techniques and integrating technology. Instructional technology has a significant
effect on the quality of teaching and learning (Earle, 2002), and integrating technology into
instruction is important to increase students’ learning and achievement (Izmirli, & Kurt, 2009).
Technology can increase the quality of mathematical investigations, portray meaningful
mathematics ideas to students and teachers from multiple perspectives, and change traditional
ways of doing mathematics (NCTM, 2000). According to NCTM’s *Principles and Standards for
School Mathematics* (2000), technologies not only increase students’ understanding and learning
of mathematics but also help teachers make instruction more effective and meaningful for
students.

While technology is powerful when used as a teaching and learning tool, as cautioned by
Heid and Blume (2008), technology-assisted approaches are not guaranteed to solve all problems
faced in education or to automatically enhance students’ learning of mathematics. Hence, the
quality of instructional technology used in the teaching and learning of mathematics is the
problem to be considered under investigation in this study.
1.1 Statement of Problem

Mathematical thinking has become more important in today’s world. Students can understand and learn mathematics more intensely through technology. Using technology to support students’ understanding of mathematics requires: 1) effective mathematics teaching and mathematical tasks; 2) teachers’ integration of technology; and 3) teacher preparation to use technology.

1.1.1 Effective mathematics teaching.

Effective mathematics teaching is necessary for all students in all classrooms to improve their understanding of mathematics. However, “the quality of mathematics teaching is highly variable” (NCTM, 2000; p.5). Teachers have different teaching styles and strategies to teach particular mathematics ideas, and there is no certain way to teach. Teachers’ knowledge and understanding of mathematics is a key factor influencing decisions and actions in their mathematics classroom to enhance their students’ learning (Anthony & Walshaw, 2009; Ball, Thames, & Phelps, 2008).

One of the roles of mathematics teachers is to provide different opportunities to their students to develop mathematical thinking. Teachers need resources to increase their knowledge and refresh their strategies for effective teaching and learning in mathematics (NCTM, 2000). Teachers determine the mathematical tasks that will be used during mathematics lessons and design how to implement these tasks in class to improve students’ thinking. A mathematical task is defined as “a classroom activity, the purpose of which is to focus students' attention on a particular mathematical concept, idea, or skill” (Henningsen & Stein, 1997, p. 528). Research
indicates that mathematics tasks are important and central for students’ learning and helping them to improve the use of reasoning skills (Boaler & Staples, 2008; Stein & Lane, 1996). Focusing on the connection between tasks and student thinking, the selection of high-level tasks (e.g. task that promote higher order thinking) for mathematics instruction, and implementing these tasks in ways that maintain high-level cognitive demands, are other essential roles of teachers (Boston & Smith, 2009; Stein, Grover, & Henningsen, 1996).

The choice of mathematical tasks has important implications for students’ understanding of the discipline of mathematics and for the quality of their mathematical thinking and learning. Thus, it is important to understand the role that technology might play in relation to the tasks that teachers choose to enact with their students.

1.1.2 Teacher integration of technology.

The presence of technology in itself may not be enough to promote effective teaching and learning; it is also important how the technology is used or implemented, poorly or well, as a teaching tool (Middleton & Murray, 1999; NCTM, 2000). Mathematics teachers’ roles are vitally important in the mathematics classroom for the effective use of technology in ways that supports students’ mathematics understanding (NCTM, 2000). Mathematics teachers are not supplanted by technology, but make decisions about how and when to integrate technology as a supplemental tool in the teaching and learning environment (NCTM, 2000).

Teachers should attend to how technological tools support students’ mathematics thinking (NCTM, 2000) and how such technologies are used for different learning goals (Chance, Ben-Zvi, Garfield, & Medina, 2007). Sherman (2014) highlighted the importance of
using technology to help students increase their high-level mathematical thinking. Using technology in ways that supports students’ learning means using technological tools in ways that provide and maintain students’ engagement in high-level tasks and thinking.

Attending to the cognitive demand of technology tasks used in mathematics teaching and learning serves as a productive focus for using technology effectively; however, research indicates the complexity of teaching mathematics using cognitively challenging tasks (Boston & Smith, 2009; Henningsen & Stein, 1996). Sherman (2014) notes that teachers have difficulty maintaining high-level demands during implementation (i.e., throughout a lesson) while using technology, even though they selected and set up high-level tasks at the start of the lesson. Teachers can benefit from professional development to enact high-level tasks (Boston & Smith, 2009, 2011). Hence, teachers need training to impact the use of technology in education, and this training should begin in teacher preparation programs.

1.1.3 Teacher Preparation.

Training to use technology effectively, in ways that support students’ learning of mathematics, needs to begin in teacher preparation programs. Future educators are prepared to gain pedagogical and subject matter knowledge and experience early teaching practice in teacher preparation programs (Feuer, Floden, Chudowsky, & Ahn, 2013). In addition, teacher preparation programs should provide what prospective teachers need in their real classroom, including educational technologies (Edutopia, 2008). As Niess (2008) mentioned, “with the addition of an integration of new and emerging twenty-first century technologies as tools for
learning, the preparation of teachers must evolve toward preparing preservice teachers to teach in ways that help them to guide their students in learning with appropriate technologies,” (p.224).

Hence, it is imperative that training to use technology in pedagogy (processes, practices, and methods of teaching and learning) and content (mathematics subjects: e.g. number and quantity, algebra, functions, geometry, statistics, probability, and calculus) effectively begins in mathematics teacher preparation programs. ISTE (2000) has developed technology standards to prepare pre-service teachers to integrate technology in their classroom settings. Teaching through using technological tools needs to be focused in teacher preparation programs (Mishra and Koehler, 2006), as many pre-service teachers, even in-service teachers, do not know which technologies are available for teaching (Lin, 2008). The importance of teacher preparation programs cannot be ignored, because such programs can provide positive experiences of using technology for PSTs in the teaching and learning of mathematics (Browning & Klespis, 2000). Garofalo et al. (2000) promoted the appropriate uses of technology in mathematics teacher preparation, and stated, “PSTs need to develop technology skills, enhance and extend their knowledge of mathematics with technological tools, and become critical developers and users of technology-enabled pedagogy” (p. 86).

After pre-service mathematics teachers graduate, they are expected to teach mathematics lessons and hopefully to integrate technology into their teaching, but many of them have not had sufficient opportunities during coursework about how to integrate technology effectively into their lesson activities. As Johnston (2009) mentioned in his dissertation, there are multiple technology tools available for pre-service teachers, but “little is known about how pre-service elementary teachers evaluate technology tools as they plan for instruction” (p.1). Based on the
In summary, technology is important in today’s world, especially in the teaching and learning of mathematics. There are various technology tools available for teachers, and teachers need to select and implement technology in ways that support students’ learning of mathematics. Teachers need training to use and integrate technology effectively in their lesson activities, and this training needs to begin in teacher preparation programs.

1.2 Purpose of the Study

The purpose of this study is to explore how PSTs design mathematics lesson activities that integrate technology. Specifically, the researcher will examine the level of cognitive demands of the mathematics tasks in the technology activities: 1) created by PSTs for an assignment in their elementary, middle level, and/or secondary mathematics methods course, and 2) created and used by secondary mathematics PSTs during student teaching. In analyzing the cognitive demand of the technology activities, the researcher will utilize such frameworks as the “Mathematical Tasks Framework” and the “Task Analysis Guide” from the work of Stein and colleagues (e.g., Stein, Smith, Henningsen, & Silver, 2009) and the Instructional Quality Assessment (IQA) in Mathematics rubrics (Boston, 2012). These frameworks and rubrics, and their use in this study, will be described in detail in Chapters 2 and 3.
In order to better understand PSTs’ ability to use technology in instructional activities, the researcher will also administer the “Level of Technology Implementation” (LoTi) Digital Age (Learning Quest, 2011) survey. The researcher will analyze how PSTs’ level of technology implementation may influence their selection of technology tools and level of cognitive demands of the mathematics task in their technology activities. The LoTi Digital Age survey includes subsections measuring Personal Computer Use (PCU), Current Instructional Practices (CIP), and overall Level of Technology Implementation (LoTi). The LoTi survey will be described in detail in Chapter III.

1.3 Research Questions

This study addressed the following questions on relation to overall purpose of this study. The research questions are addressed in detail in Chapter III.

**Research Question One:**

- What are the cognitive demands of instructional activities when pre-service mathematics teachers are asked to integrate technology into mathematics lesson activities a) created for an assignment during the mathematics methods course; and b) created and used during student teaching? Specifically:

**Research Question Two:**

- What is the mathematics pre-service teachers’ level of technology integration?
Research Question 3:

- How is PSTs’ level of technology integration related to the level of cognitive demand of instructional tasks in PSTs’ mathematics lesson activities that integrate technology?

1.4 Significance of Study

There are two important and different approaches in considering the role of technology in addressing student learning: (a) the quality of instruction and (b) the impact on student learning. These two approaches are related to and affect the student learning in education, especially in mathematics education. Many studies investigated how technology has affected students’ learning and understanding of mathematics (such as Shin, Sutherland, Norris, & Soloway, 2012) and a few key studies have focused on how using instructional technology has influenced teachers’ implementation of tasks and students’ complex thinking in the classroom (e.g., Sherman, 2014). Hollebrands, Conner, and Smith (2010) stated that the majority of studies have focused on the use of technology and how it affected the learning of the NCTM Content Standards (e.g., Number and Operation, Algebra, Geometry, Measurement, and Data Analysis and Probability), but fewer studies have focused on how technology supports learning of the NCTM Process Standards (e.g., Problem Solving, Reasoning and Proof, Communication, Connection, and Representations). This study makes a contribution and extends the work of Sherman by focusing on PSTs’ attention on the cognitive demands of instructional tasks that incorporate technology.

Rice, Johnson, Ezell, and Pierczynski-Ward (2008) remarked that addressing the needs of learners, using best teaching strategies, and teaching the standards are not enough without the
integration of technology for the process of effective planning. There are still few studies focused on how PSTs use and integrate instructional technology for instruction. Johnson (2012) examined ways that PSTs use technology broadly, such as for instructional display or to support students in problem solving. By examining the cognitive demands of the lesson tasks and activities planned by PSTs, this study expands Johnson’s work by focusing on students’ level of engagement with the technology and the type of student thinking promoted by the PSTs’ technology activities.

This study aims to investigate PSTs’ integration of technology and how the integration of technology influences the level of cognitive demands of the mathematics tasks in their mathematics technology activities. This study also focuses on PSTs enrolled in elementary, middle level, and secondary mathematics method courses and student teaching. Through a review of results of PSTs’ responses to the survey instrument (LoTi Digital Age survey) and the cognitive demands of mathematical tasks in PSTs’ technology activities, this study will offer suggestions regarding teacher preparation to integrate technology into mathematics instruction in ways that support students’ learning. If PSTs are trained how to select and implement cognitively demanding tasks that incorporate technological tools, they may transfer their knowledge and experience into their future classroom and design high-level technology tasks in mathematics. The results of this study might also generalize to other teacher education programs in which mathematics PSTs engage in analyzing the level of cognitive demand in tasks, lessons, and lesson planning.
1.5 Limitations

Because this study examines a complex issue, several limitations are introduced. First, the sample size of this study is moderate for use of a survey instrument (20); however, the sample size exceeds that of many previous studies examining the cognitive demands of lesson activities (e.g., Boston & Smith, 2009, 2011), or using case study methodologies (e.g., Sherman, 2014). Second, the result of this study may be unique just for sample of this study (i.e., PSTs in a specific teacher preparation program, taking similarly-designed mathematics methods courses, at the same University) and potentially may not generalize to other populations. Third, this study uses a non-probability sample, which limits generalization. Non-probability samples do not truly represent a population. Finally, only a sample of lesson activities will be collected from PSTs, and these lesson activities may not represent pre-service teachers’ overarching view of the selection and/or creation of mathematics tasks and integration of technology.

1.6 Delimitations

Classroom observation of PSTs during their student teaching placements could have been potential data for this study, but the researcher is specifically interested in pre-service teachers’ creation of lesson activities and their level of technology integration. Data regarding K-12 students’ achievement will not be focused on this study, but other studies can use these data. In this study, samples of students’ work will be used to assess the extent to which the technology-based lesson activity engaged students in cognitively challenging mathematical work and thinking, but no state-assessment scores or other student-level assessment data will be collected or analyzed. This decision is appropriate given this study’s focus on lesson activities created by
pre-service teachers, who will not have their own classroom or students at the time of the study, but will be student teaching in the classroom of (and with the students of) a cooperating teacher.

1.7 Organization of the Document

This document has five major segments: Introduction, Literature Review, Methodology, Results, and Discussion. Chapter I includes the introduction, statement of the problem, purpose of the study, research questions, significance of the study, limitations, and operational definitions. In the next chapter, the literatures on mathematical tasks, PSTs’ training, and PSTs’ knowledge of integrating instructional technology for mathematics instruction are focused on in relation to the research questions. Frameworks for the levels of cognitive demand and use of instructional technology by teachers are discussed in detail in Chapter II. Chapter III describes the research methods used to answer the research questions; in particular, which instruments are used and how data will be collected and analyzed. Chapter IV discusses results of data analysis and Chapter V presents the results of this study, case studies, conclusions, and recommendations for further study.
1.8 Definition of Terms

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

- **Cognitive Demands**: Stein, Smith, Henningsen, and Silver (2000) defined cognitive demand of a mathematical task as “the kind and level of thinking required of students in order to successfully engage with and solve the task” (p. 11).
- **Mathematical Task**: is defined as “a classroom activity, the purpose of which is to focus students' attention on a particular mathematical concept, idea, or skill” (Henningsen & Stein, 1997, p. 528).
- **Technological Tools**: The use of technology tools to enhance the mathematics teaching and learning process. These tools include but not limited: graphic calculators, computer, Internet sources, SmartBoard, software, applets, document cameras, virtual manipulatives, multimedia.
- **Technology Integration**: The use of technology into lesson practices and also lesson plans.
- **IQA toolkit**: IQA has sets of rubrics to measure the quality of instruction and learning by lesson observation and students’ work.
- **LoTi Framework**: Level of Technology Innovation is an assessment instrument to identify levels of technology implementation of Pre-service Teacher, In-service Teacher, Instructional Specialist, Media Specialist, Administrator, and Higher Education Faculty. The LoTi Digital-Age Survey measures three primary indicators:
Current Instructional Practice (CIP), Personal Computer Use (PCU), and Levels of Technology Implementation (LoTi)

- **Pedagogy**: Instructional methods used by teachers
- **SmartBoard**, which is interactive whiteboard
- **Internet Source**: which is basically webpage, and contains different types of sources, including multimedia.
- **Graphics Calculator**: which is a handheld calculator, and help students to visualize and better understand plotting graphs, solving simultaneous equations, and other tasks.
- **Task**: A task is a classroom activity that focuses students' attention on and contributes to the development a particular mathematical idea.
- **TPACK**: Technological Pedagogical Content Knowledge 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, Suharwoto, Lee, & Sadri, 2006, p.1).
- **Technology Activity/Instructional Activity**: that is detailed guide for teaching lesson and address instructional activities involved in the implementation of the technology task; e.g., how the PST describes using the task within a lesson and what products would be expected of students.
1.9 Key to Abbreviations

The following abbreviations have been used in the text:

PST: Pre-Service Teacher

IQA: Instructional Quality Assessment

**LoTi Digital Age Survey**: Levels of Teaching Innovation Digital Age Survey

CIP: Current Instructional Practices

PCU: Personal Computer Use

LoTi: Levels of Teaching Innovation

NCTM: The National Council of Teachers of Mathematics

NLVM: The National Library of Virtual Manipulatives

ISTE: International Society for Technology in Education

SITE: The Society for Information Technology and Teacher Education

MTF: Mathematical Task Framework
CHAPTER II

LITERATURE REVIEW

2.1 Introduction

There is no lack of research for the use of technology in mathematics education (Sherman, 2011). As evidence, Ronau and colleagues (Ronau, Rakes, Bush, Driskell, Niess, & Pugalee, 2014) identified 164 out of 607 mathematics education dissertations between 2005-2009 focused on mathematics education technologies. However as Johnston (2012) stated, there are limited studies focused on the selection and uses of educational technologies by mathematics pre-service teachers. The following review of literature addresses the key and important ideas that served as the foundation of this dissertation. First, the researcher describes which technological tools are available to use in mathematics education. Then, the Technological Pedagogical and Content Knowledge (TPACK) framework will be discussed, as well as research on teachers’ use of technology and PSTs’ preparation to use technology. Finally, the researcher provides information about instructional quality in mathematics and the cognitive demands of mathematical tasks. These topics are important to the research in this investigation because the researcher will assess pre-service teachers’ (PST) ability to integrate technology into lesson activities in ways that support students’ learning of mathematics by analyzing the cognitive demands of technology-based instructional tasks.

2.2 Available Technology Tools for Mathematics Education

“Some mathematics becomes more important because technology REQUIRES it; some mathematics becomes less important because technology REPLACES it; and some mathematics become possible because technology ALLOWS it” (Heddens & Speer, 2006, p.61; cited from
NCTM, 1998). Education should prepare students to use mathematics in the technology-based world. Teachers and school systems have a responsibility to prepare students for real life and help them to know how to use technology when they face problems in the real world (Heddens & Speer, 2006).

There is obviously increased technology use in mathematics education from 1968 to 2009 (Ronau et al., 2014). The first hand-held calculators were presented in 1972 (Waits & Demana, 2000), the first microcomputers for school use were promoted around 25 years ago, the first graphing calculator was marketed almost 20 years ago, and we started to use the internet (i.e., World Wide Web) almost 15 years ago (Heid, 2005). However, current research indicates that instructional technology integration is not high in K–12 mathematics classrooms, especially in high schools. The use of technology decreases from elementary school to high school: 33% in elementary math classroom, 28% in middle school mathematics classroom, and 21% in high school mathematics classroom (Banilower, Smith, Weiss, Malzahn, Campbell, & Weis, 2013).

A variety of technological tools are available for teachers and pre-service teachers (PSTs) to integrate into mathematics instruction, such as virtual manipulatives, educational software, Interactive White Board, Graphic Calculators, Internet, and the like. Calculators and computers are potential tools to enhance students’ understanding and learning of mathematics (Heddens & Speer, 2006). Powers and Blubaugh (2005) highlighted that the use of technology such as computer technologies and graphic calculators by PSTs into their future teaching is one of the ways to adapt mathematics education into the technology era. However, some PSTs and even in-service teachers do not know how to implement technological tools or which technological tools
are available for teaching. As Gorder (2008) stated, many teachers do not feel comfortable integrating technology.

Ronau et al. (2014) examined 480 dissertations from 1968-2009 in which technology has been studied, and they found that 703 technology types have been addressed in these dissertations. Computer software (n=268) is the most studied technology, and Internet technologies (n=112) are the least addressed technology in these dissertations. In addition, calculators are addressed 175 times, and other technologies (such as Interactive whiteboard, email, Probeware, computer programing, etc.) are mentioned 148 times. Furthermore, Polly (2014) observed three teachers and found that teachers rarely used the desktop computer or iPad computer, however teachers used the document camera and projector in every lesson to demonstrate mathematical tasks and students’ work.

Ahmad and colleagues (2010) expressed that the integration of technological tools can offer variety for students’ learning in the technological age. However, Wachira and Keengwe (2011) found that while computers with Internet, textbook publishers’ tutorial sites and CD-ROMs, and calculators are commonly available technologies in schools, technology integration remains limited. In the next section, available technology tools for mathematics instruction are explained in further detail.

2.2.1 Calculators.

The calculator is most commonly used and basic tool in mathematics education. There are two main forms of calculators: the scientific and graphing calculators. Use of graphing and/or
scientific calculators are observed infrequently at the elementary school level, in contrast to most frequently at the high school level (Banilower et al., 2013).

The National Council of Teachers of Mathematics (NCTM) highlights the importance of integrating calculators into instruction and recommends that schools and teachers make calculators available for all students from kindergarten to college level. Similarly, Heddens and Speer (2006) stated that incorporating calculator into instruction could be effective into mathematics program at all grade levels, because the use of calculators help students to access rich problem solving experiences and can positively affect the learning and teaching of mathematics. Researchers suggest that to support students’ learning in mathematics, the calculator is not used to replace students’ thinking or students’ ability to perform basic procedures (Pomerantz, 2009; NCTM, 2005; McCauliff, 2004). Some mathematics concepts are limited to engage and experience with only pencil and paper; however, use of calculators allows students to access and explore these concepts (Pomerantz, 2009).

The instructors should consider use of calculators as an integral teaching and learning tool (Heddens & Speer, 2006), because calculators allow students to reach higher-order-thinking (Pomerantz, 2009; NCTM, 2011). In addition, “when students are engaged in solving problems, formulating and applying strategies, and reflecting on results, a calculator is an important enabling tool” (Reys & Arbaugh, 2005, p. 93). Developing students’ ability of using calculators is important, and the role of the instructor is to help students to understand how and when to use a calculator (Heddens & Speer, 2006). The skill, knowledge, and ability of classroom teachers shape and affect the use of calculators. For example, “in the classroom of a thoughtful and talented teacher, the calculator can be especially useful in developing understanding of place
value, reversibility, relationships among numbers, operations, decimals, metric measure, prime factoring, composites, changing fractions to decimals, and percentages, as well as making mathematical estimates” (Heddens & Speer, 2006, p. 60).

Calculators should be integrated into instruction in order to enhance student understanding of mathematical concepts (Heddens & Speer, 2006); however some researchers argue that instruction with calculators in elementary school poses a threat for students, so teachers should not use a calculator until students master the basic facts. Niess (2006) indicated that there is still a challenge for mathematics teachers to examine using calculators as tools for students’ thinking rather than as tolls to replace their thinking. Teachers need the ability to make choices about using calculators in ways that supports students’ thinking rather than to replace students’ development of mathematical knowledge and understanding.

2.2.2 Computers.

Computer and Internet are more commonly used sources for teachers in the teaching and learning environment. Teachers can access teaching materials, teaching ideas, lesson plans, and activities through searching on the Internet. In today’s classrooms, computer can be connected to the Internet, and interconnected with interactive white board, projectors, and/or printers to share information with students.

Smerdon, Cronen, Lanahan, Anderson, Iannotti, and Angeles (2000) reported that almost all (99%) public schools had computers available somewhere in the schools. In 2009, 97% of teachers had at least one computer located in their classroom and 93% of these computers had available Internet access in public schools (U.S. Department of Education: National Center for
Educational Statistics, 2010). In addition, the Internet is used on a weekly basis in 43% of elementary mathematics classes, 26% of middle level mathematics classes, and 11% of high school level mathematics classes (Banilower et al., 2013).

Over the last 10 years, computer availability has increased in the classroom. However, some teachers do not have enough experience to integrate computers in the classroom, and some teachers do not allocate time to prepare lesson plans and teach mathematics using computers (Heddens & Speer, 2006). Ke (2008) studied the effect of computer games, and concluded that use of computer games increases students’ attitudes positively toward mathematics; however, it does not affect students’ cognitive mathematical achievement.

2.2.3 Interactive White Board.

The Interactive White Board (IWB) has become as popular over the last few years as other technologies. IWB is also referred to as SmartBoard or White Board. IWB is a large and touch-sensitive device (Smith, Higgins, Wall, & Miller, 2005) that connects to a computer and a multimedia projector through installed software. Swan, Schenker, and Kratcoski (2008) explained IWBs as:

“Virtually anything that can be done on a computer can be done on an interactive white board, with the advantage that interaction involves fingers and pens and so is more kinesthetic, drawing, marking and highlighting of any computer-based output is supported, a whole class can follow interactions, and lessons can be saved and replayed”.

(p. 3290).
IWB has flexibility and efficiency features to support teaching and learning; however, the U.S Department of Education (2010) stated that only around 25% of teachers in the USA had access to interactive whiteboards as needed for everyday uses. Lai (2010) indicated that practice in using IWB helps teachers to integrate IWB in a meaningful way into instruction. Student learning, motivation, and achievement can be affected by the use of IWB, but these effects are related to teachers’ confidence, training, practice time, and technical support in using the IWB (Digregorio & Sobel-Lojeski, 2009).

2.2.4 Instructional Software and Web-Based Resources.

There are several types of instructional software programs available for teachers to use in their classrooms. Various types of software are categorized as exploration tools, simulations, educational games, drill and practice, problem solving, and tutorials (Heddens & Speer, 2006), and teachers should be critical to use them. Some examples of instructional software and web-based resources are GeoGebra, IXL, Khan Academy, National Library of Virtual Manipulatives (NLVM), and NCTM Illuminations, which are discussed below.

*GeoGebra.* GeoGebra is dynamic geometry software including geometry, algebra and calculus features and is an open source tool for teaching and learning mathematics (Hohenwarter, Hohenwarter, Kreis, & Lavicza, 2008) from middle school to higher education. Hohenwarter and Fuchs (2004) described uses of GeoGebra for demonstration and visualization, discovering mathematics, and preparing teaching materials.
**IXL.** IXL is an example of a drill and practice site for kids preschool through high school and can provide independent practice. IXL offers over 2,000 math-practice modules, and almost all these practices meet Common Core mathematics standards (IXL website).

**Khan Academy.** Khan Academy is a free tutorial site for anyone anywhere. The site offers practice exercises, instructional videos, and personalized learning experience to engage students for all ages. Khan Academy has over 5,500 instructional videos, and mathematics is the richest content area (3,500 of which teach math concepts) (Khan Academy Website).

**Virtual Manipulatives.** Use of virtual manipulative can help students to visualize relationships (Heddens & Speer, 2006). Moyer, Bolyard, and Spikell (2002) described a virtual manipulative as "an interactive, web-based visual representation of a dynamic object that presents opportunities for constructing mathematical knowledge" (p.373). Virtual manipulatives allow students to understand mental (abstract) ideas and symbols, and demonstrate these abstract ideas in more meaningful ways to students (Durmus & Karakirik, 2006).

National Library of Virtual Manipulatives (NLVM) and the National Council of Teachers of Mathematics (NCTM) Illuminations are popular web-based virtual manipulatives tools. NVLM is a supported project by the National Science Foundation to produce interactive virtual manipulates (NVLM, 2015; Durmus & Karakirik, 2006), and is a digital library containing Java applets and activities for K-12 mathematics (NVLM, 2015).

NCTM Illuminations allows students and teachers to access quality standards-based resources (lesson plans, activities, and games), including interactive tools to support teaching and learning mathematics (see the Illuminations.NCTM.org website). NCTM Illuminations provides
students and teachers electronic sources to improve mathematics learning and teaching (Keller, Hart, & Martin, 2001). All interactives and lessons are categorized based on grade levels and the NCTM Content Standards and Common Core Mathematics Standards. Hart, Keller, Martin, Midgett, and Gorski (2005) described features of NCTM Illuminations as:

- Online, interactive, multimedia resources (primarily using applets and videos)
- Internet-based lesson plans
- Reviewed and categorized external Web resources
- A Web design framework that organizes and presents the content in such a way that the design itself helps illuminate Principles and Standards and makes all content as usable and accessible as possible (p.222).

Wiki and Blogs. Wiki and Blogs can be used in mathematics teaching. According to Krebs, Ludwig, and Muller (2009) wiki is one of the essential tools to communicate and cooperate with others. Also a blog or a wiki can be used to provide a space for students to record their initial thoughts, questions, and solutions, and posts in blog are only viewable by the instructor and author of post. For collaborating works, wiki can be provided to students to work with their classmates. Primarily technological tools in distance education, wiki and blog are rarely used in mathematics education when compared to other content areas and disciplines.

2.2.5 Other Technologies.

Another technological tool in math education is the Mobile Device (e.g., smartphone, iPod, tablet PCs, handheld gaming devices, and so on), which is a new trend in educational settings. Mobile devices allow students to connect to the digital world while sitting in the
classroom (Franklin & Peng, 2008). Baya’a & Daher (2009) highlighted how the use of mobile phones in education can enable student learning of mathematics as students can explore mathematics independently; help students to learn mathematics through collaboration across physical locations; demonstrate real life situations; help student to learn mathematics easily and visualize complex mathematical contents.

Multimedia is another tool used in education. Multimedia offers a combination of different content such as audio, text, image, video, animations, and etc. Teachers would need to be comfortable with technology and know how to integrate multimedia technology in the learning environment (Heddens & Speer, 2006). Multimedia tools can be used by teachers as a classroom application, and students can use them as productivity tools (Heddens & Speer, 2006).

Ahmad, Yin, Fang, Yen, and How (2010) compared the impact on student achievement of traditional methods in teaching mathematics with interactive approaches. The findings of this study showed that students’ understanding is better when teaching with multimedia than traditional methods, because multimedia provides a visual presentation, 3D shapes, and helps students to easily engage with mathematics.

There is variety of technology tools available for teachers and PSTs to teach mathematics. This dissertation focuses specially on graphing calculators, Internet sources, and interactive whiteboards. With such a variety of tools available, it is important for teachers to know how to use them in ways that truly support students’ learning of mathematics. In the next section, I present a framework for considering the knowledge that teachers need to successfully integrate technology into instruction in a specific content area.
2.3 Technological Pedagogical Content Knowledge (TPACK)

Technological Pedagogical Content Knowledge (TPACK) is a framework for describing the knowledge teachers need to integrate technology into instruction (Mishra & Koehler, 2006). The idea of TPACK is based on the idea of Pedagogical Content Knowledge (PCK) that was originally described by Shulman in 1986. Shulman (1986) described PCK as the integration of teachers’ content knowledge with pedagogical knowledge in their teaching practice. PCK describes pedagogical knowledge and strategies for teaching specific to a subject area or content topic. For example, asking good questions is a component of pedagogical knowledge of teachers, and understanding slope of a line as a constant rate of change is a component of content knowledge. PCK would involve knowing what questions to ask to support students’ understanding of slope of a line as a constant rate of change.

The knowledge of technology was added to the original components of PCK, and is called the TPACK model. First, Mishra and Koehler (2006) added technology knowledge within PCK. Then, the PCK framework was extended to include Technology Knowledge as an additional component and to delineate its relationships with other components. Content Knowledge (CK), Pedagogy Knowledge (PK), and Technology Knowledge (TK) are the three main components, and technological pedagogical content knowledge (TPACK or TPCK) is a combination of the main components (Koehler & Mishra, 2008) and the heart of the TPACK framework. Figure 1 demonstrates the intersections and combinations of the TPACK model (retrieved from http://tpack.org)
Figure 1. The TPACK framework and its knowledge components (Koehler & Mishra, 2009, p. 63, and Koehler, n.d.).

**Content Knowledge (CK)** is a teachers’ knowledge of subject matter. This knowledge includes theories, organizational framework, knowledge of concepts and ideas, knowledge of evidence and proof, and approaches in a particular subject matter (Shulman, 1986). In the case of mathematics, number and quantity, algebra, functions, geometry, statistics, probability, and calculus are some examples of CK.

**Pedagogical Knowledge (PK)** is teachers’ knowledge of processes, practices, and methods of teaching and learning (Harris, Mishra, & Koehler, 2009). This knowledge includes how students learn, assessment, teaching strategies, evaluation techniques, classroom management skills, and lesson planning. Learning theories and instructional methods are considered under the PK (Ozgun-Koca, Meager, & Edwards, 2009/2010).
Technology Knowledge (TK) is teachers’ ability and knowledge of using, implementing, and adapting technology-oriented tools. TK also refers to knowledge of technologies in teaching and learning, including such digital technologies as the Internet, interactive whiteboards, and graphic calculators and even basic form of technologies as paper and pencil or other instructional tools.

Pedagogical Content Knowledge (PCK) is the interaction of pedagogical and content knowledge, defined as the awareness of best instructional approaches and content arrangements for effective teaching (Shin, Sutherland, Norris, & Soloway, 2009). Ozgun-Koca, Meager, and Edwards (2009/2010) described PCK as “how particular pedagogical methods might help (or hinder) students' learning of specific content” (p.11).

Technological Content Knowledge (TCK) is knowledge of technology and content, and defined as “understanding of the manner in which technology and content influence and constrain one another” (Koehler & Mishra, 2009, p. 65). TCK can be teachers’ knowledge of technology and mathematics, and ways that a teacher knows how to use technology to support their own understanding of mathematics. Ozgun-Koca and her colleges provide an example of TCK: “technology can be used to explore the fact that a quadratic with integer coefficients is highly unlikely to be factorable, drawing attention to and questioning the traditional content of school mathematics” (p.11).

Technological Pedagogical Knowledge (TPK) is the interaction of technological and pedagogical knowledge, and defined as “an understanding of how teaching and learning can change when particular technologies are used in particular ways” (Koehler & Mishra, 2009, p.65), or how the use of a technological tool changes teaching and learning (Harris, Mishra, &
Koehler, 2009). TPK is knowledge of how to use technology during instruction, how technology supports teaching, and how to teach with technology.

**Technology, Pedagogy, and Content Knowledge (TPACK)** is teachers’ knowledge of the integration of technological tools to transform teaching practices in a specific content area. Niess (2005) defined TPACK as “the integration of the development of knowledge of subject matter with the development of technology and of knowledge of teaching and learning” (p. 510). TPACK is necessary for teachers to integrate technologies into teaching and learning mathematics.

Billions of dollars have been spent for training and technology purchases to teach teachers new ways of integrating technology into their teaching. Teachers need different types of knowledge for technology integration, and the TPACK framework identifies these types of knowledge (Mishra & Koehler, 2006). Good teaching with technology requires three core components: content, pedagogy, and technology, and also their combinations (Koehler & Mishra, 2009). Even when teachers are strong in content and pedagogy, they can be uncomfortable when technology is included into content and pedagogy (Gorder, 2008).

In the last few years, the TPACK framework has received attention by researchers. TPACK was studied in 16 dissertations and 56 peer-reviewed published articles since 2005 (Chai, Ling Koh, Tasi, & Tan, 2011). Additionally, Mishra, Koehler, and Henriksen (2011) stated that over 25 dissertations and over 60 articles, symposia, and conference presentations were identified in the official website of TPACK wiki list over the last few years.
The subject matter knowledge and pedagogical content knowledge of teachers are two major factors that are needed by teachers to teach mathematics and also to adapt mathematical tasks and lessons (Sullivan, Clarke, & Clarke, 2013). In this study, TPACK is important because teachers’ preparation programs previously focused only on pedagogical and content knowledge. With technology being an important part of education systems as described in this chapter, the integration of technology must be considered in teacher preparation programs. TPACK knowledge must be seen as essential knowledge of all three concepts together. Teachers make decisions not only about which technological tools to use during instruction but also how these technologies should be used to support students’ learning, thinking, and understanding of mathematical ideas.

2.4 Teachers’ Use of Technology

There is wide agreement and belief that student learning can be positively affected by the use of technology (Polly, Mims, Shepherd, & Inan, 2010). While improving students’ achievement through the integration of technology is the topic of much research, the role of the teachers, and whether they are ready to use technology effectively in their classroom, should also be considered (Polly et al., 2010).

“There is no “one best way” to integrate technology into curriculum” (p. 62), and integration of technology should be structured and designed for specific subject matters and grade levels (Koehler & Mishra, 2009). In addition, teachers must be equipped with skills to integrate technology to effectively teach subject matter content in the classroom (both real and virtual) (ISTE, 2000). Ives, Lee and Starling (2009) describe teacher’s decisions on how to implement curriculum materials into instruction as: “1) how to organize class activities for whole
class or small group work, 2) the tasks to pose and key questions to ask, and 3) how resources will be used” (p.1).

Today’s students must be provided technology-support learning, and teachers must be prepared to give them these opportunities. Today’s teachers must know how technology can support students learning, and be prepared to integrate technology (ISTE, 2000). There are many factors for effective technology integration, “but the most important factor is the teachers’ competence and ability to shape instructional technology activities to meet students' needs (Gorder, 2008, p.63).

Fletcher (2006) reported that technology integration is deficient and limited in the pre-K through 5th grades in public schools. One of the reasons for the limited use of technology is that teachers face some barriers when they integrate technology into the classroom (Wright & Wilson, 2011). Generally technology is used by teachers for keeping records, creating lesson plans, and communicating with peers and school (Wachira & Keengwe, 2011; Rehmat & Bailey, 2014). Lack of time, lack of access to a variety of technology, lack of technology skills, and lack of training are mostly identified as factors why teachers do not feel well prepared to integrate technology into their classrooms. Additionally, many teachers do not feel prepared to use a variety of technology, and teacher’s knowledge of technology integration is limited (Mishra & Koehler, 2006). Lack of training is a barrier, and to handle this barrier, integration of technology should be incorporated into professional development experiences (Fletcher, 2006). These factors should be considered in pre-service teachers programs to help to direct PSTs to successfully use technology in their future classrooms.
Today’s students are called digital natives, because they have grown up in a technology-based world (Prensky, 2001). However, many of today’s teachers can be considered digital immigrants (Prensky, 2001), because they did not learn using technology as a student themselves or receive training in their teacher preparation programs. As such, teachers may not be aware of ways to integrate technology into the classroom. Teachers are struggling to teach students that think and learn differently from their teachers (Prensky, 2001). As digital immigrants, many teachers may not think of ways to use technology in the classroom.

Teachers’ readiness and their comfortable level with technology influences their technology integration into classrooms. Teachers’ readiness is dependent on training, preparation, and work environments. For example, teachers who have low comfort-levels with technology incorporate it less frequently into their lesson plans (Jones, 2001). Jones (2001) identified challenges for teachers: learning new software and developing lesson plans in which technology is integrated.

Other researchers have studied teachers’ use of technology. For example, Goos and Bennison (2008) studied secondary mathematics teachers’ use of technology in classrooms, and they conducted two surveys for 485 mathematics teachers’ use of computers, graphing calculators, and the Internet. More than 85% of schools stated graphing calculators, and almost all reported that spreadsheet programs are available to use in schools. However there is limited availability of graphing software (i.e. dynamic geometry, statistical programs, and computer algebra). Only 26.6% of teachers had been using graphing calculators, while 12.3% of teachers had been using the Internet, and 42.7% of them had been using the computer for more than five years. Twenty six percent of teachers took professional development training related to
computers, the Internet, and graphics calculators; while 16.7% of teachers indicated that they never participated any professional development related to computers, the Internet, and graphing calculators.

Bozkurt (2011) observed 32 elementary school teachers in the classroom after they received four weeks in-service training in order to integrate technology in the classroom. The participating teachers were inexperienced in using technology. Powerpoint was the most widely integrated technology in the classrooms, but it was used only 10 times, while 8 teachers used simulation in the classroom. Other technologies used were website, Flash, office, and delineascope (which is a type of projector, and could project both slides and print images), but they were integrated only a few times. The author also mentioned that after participating in in-service training, teachers better understood how to select the technology for teaching purposes.

Cottle (2010) studied 21 elementary and 22 middle school teachers to determine the influence of the professional development course on participants through pre-post survey and focus group interviews. The researcher found, “(a) a lack of time to learn, practice, plan, and use technology with students, (b) lack of sufficient technology assistance, (c) equipment failure, (d) access to technology, (e) lack of technology knowledge or expertise for substitute teachers, and (f) other priorities (e.g., statewide testing, new textbook adoptions)” (p.75) are the main barriers of using technology. Participating teachers stated that they increased the use of technology or learned new technologies from the professional development course, including SmartBoard, Skype, Microsoft, wiki, document camera, Adobe, and some other technologies. Some teachers reported that they were previously not comfortable and did not experience the use of technology into their classroom, such as SmartBoard. After taking professional development, they felt more
comfortable using this technology. Overall, results show that professional development courses significantly increased participants’ levels of current instructional practices.

Rakes, Fields, and Cox (2006) studied the influence of teachers’ technology use on instructional practices, and surveyed 86 fourth and eighth grade teachers. They determined that lack of access to equipment or lack of time to use technology affects teachers’ ability of using technology, and participating teachers’ ability of using technology is limited. In addition, teachers’ personal computer use at home or in the workplace and their levels of comfort levels with computers were lower than expected.

Kurt (2010) studied teachers’ technology use in elementary education, and collected data from 29 teachers through using open-ended interviews, a survey, classroom observations and an examination of relevant documents. The result shows that teachers aim to use available technologies such as TV, cassette players and VCD player for showing video for instruction and administrative purposes. These technologies are outdated types of technologies.

2.5 Preparing Pre-Service Teachers to Teach with Technology

The United States Department of Education's Preparing Tomorrows Teachers to Teach with Technology (PT3) has supported 441 grants since 1999 (U.S. Department of Education, n.d.), and provided millions of dollars to educational institutions to better prepare in-service teachers and PSTs to integrate technology effectively in education (Polly et al, 2010). Educational organizations such as the International Society for Technology in Education (ISTE), National Council of Teacher Education (NCTE), Ministry of National Education, the Society for Information Technology & Teacher Education (SITE) all express the need to increase student
learning by using technology in the classroom. Hence, teachers need to be trained to use technology in the classroom, and this training should begin in teacher preparation programs.

ISTE (2000) has developed technology standards and guidelines for teacher preparation program to prepare teachers to integrate technology, and also ISTE (2008) has developed national educational technology standards and performance indicators for teachers. The five categories of ISTE standards (2008) are: (Appendix J)

- Facilitate and Inspire Student Learning and Creativity
- Design and Develop Digital-Age Learning Experiences and Assessments
- Model Digital-Age Work and Learning
- Promote and Model Digital Citizenship and Responsibility
- Engage in Professional Growth and Leadership

ISTE (2000) recommend that teacher candidates “must continually observe and participate in the effective modeling of technology use for both their own learning and the teaching of their students” (p. 7). Many teacher education programs have started to offer technology courses for PSTs to improve their skills of integrating technology (Polly et al., 2010). However, these courses often only offer basic technology skills (Kay, 2006). For example Blakeney (2014) found that PSTs were highly capable with using basic technologies, however their proficiency level was low with more difficult technologies and instructional technology. Garofalo, Drier, Harper, Timmerman, and Shockey (2000) identified three uses of technology in teacher education. In the first approach, the PST is the primary user of the technology. Garofalo et al. (2000) offer examples of the first approach as “PSTs are being prepared to use technology productivity tools for word processing, grade and record keeping, web page production, and
presentations” (no page number). The second approach is to prepare PSTs to use subject-specific software and websites to design or create lecture, presentation, lesson, and assessments. The third approach is to prepare PSTs to guide their future students about how to use technology, “such as spreadsheets, graphing calculators, dynamic geometry programs, and playable websites to explore mathematics concepts and use mathematics to solve problems in applied contexts” (p.67).

In addition to technology courses, PSTs can also improve their technology integration skills from field experiences and student teaching (Chen, 2010). Upon completion of cultivating student teaching or internships experience, PSTs should be able to “identify, evaluate, and select specific technology resources available at the school site and district level to support a coherent lesson sequence, [and] create and implement a well-organized plan to manage available technology resources, provide equitable access for all students, and enhance learning outcomes” (ISTE, 2000, p.20). For example, Blakeney (2014) investigated four pre-service elementary education teachers’ self-efficacy beliefs regarding technology integration in the classroom environment. All participants mentioned that their instructors integrated PowerPoint and computer in the instructional process, and two mentioned the SmartBoard. Technology proficiency levels of PSTs were low for using SmartBoard for instructional purposes, Skype, document camera, content specific software, and accelerated reader. Participants showed medium confidence with using Ipad, and high confidence with using interactive whiteboard. SmartBoard, classroom calculators, teacher laptop, computer, document camera, and overhead projector were utilized in the classroom in which they were placed for the student teaching field experience. Overall result suggests that PSTs’ self-efficacy beliefs of using technology for instructional purpose was improved over the teacher preparation course.
Schrum (1999) offered three key experiences for PSTs preparation to integrate technology. First, PSTs must be given opportunities to experience various types of technology tools in method courses. Second, PSTs should be taught how these technologies can be integrated into their specific subject areas. Finally, PSTs must be supported and given adequate opportunities to apply and implement what they learned on technology integration in the field experience.

Technology must be a central focus of courses preparing PSTs for teaching and learning (ISTE, 2000; Thompson, Schmidt, & Davis, 2003). PSTs can understand the importance of integrating technology in the classroom (Thompson, Schmidt, & Davis, 2003). Hence, as Polly et al. (2010) indicate, PSTs’ preparation to use technology in their future classrooms should be seen as an essential part of method courses, and not independent of each other. When the use of technology is incorporated into methods courses, PSTs can have the experience of integrating technology, be aware of which technologies are available for them in teaching mathematics, learn to use technology with different teaching strategies (Powers and Blubaugh, 2005), and learn how to plan successful instructional activities in which technology is integrated.

Technology courses offered in teacher education programs should be connected with methods course (Kay, 2006), because only taking technology course does not show PSTs’ ability to successfully integrate technology (Wang, 2002). Teacher educators might encourage PSTs to make more practices and help them to implement technology plans into the classroom (Wright & Wilson, 2011). Bell (2001) offered research questions for mathematics education that should be considered by researchers: “How do mathematics teacher educators structure methods courses so that preservice teachers learn how to use a variety of technologies and develop sound
pedagogy?” and “How do mathematics teacher educators prepare preservice teachers for the future, where emerging technologies will have implications for their roles and their curricula?” These questions highlight the importance of methods courses in which PSTs can increase their ability to integrate technology.

Some researchers have developed guidelines to direct PSTs to integrate technology successfully. For example, Garofalo, Drier, Harper, Timmerman, and Shockey (2000) identified five guidelines for PST to plan for instruction using technology: 1) Introduce technology in context; 2) Address worthwhile mathematics with appropriate pedagogy; 3) Take advantage of technology; 4) Connect mathematics topics; 5) Incorporate multiple representations (p.67).

In addition, Bell (2001) provides guideline for teacher educators to prepare PSTs to use of technology. These include PSTs to:

- Appropriately incorporate technology into their teaching, in regular classrooms equipped with graphing calculators and a computer and in computer labs, to enhance students’ conceptual understanding of mathematics and its applications.
- Become savvy using, evaluating, and choosing technologies.
- Modify their curricula and develop materials to capitalize on available technologies.
- Learn how to be resourceful and learn how to lobby to get what they need.
- Change the educational world; emerging technologies will have curricular and instructional implications.
- Develop professional development models for both teachers and teacher educators (e.g., workshops and panel discussions at AMTE and the National Council of Mathematics Teachers, on-line courses for mathematics teacher educators, virtual subgroup meetings).
- Develop mechanisms for teachers and teacher educators to share materials and successful efforts.
- Develop a research agenda to investigate the effects of effective technology use on students' learning of mathematics.

2.5.1 Developing TPACK in Teacher Education Programs.

Chen (2010) highlighted that “preservice teachers’ obtaining technology skills needs to be complemented by pedagogical knowledge and extensive practice of how to use their technology skills to augment student learning” (p.33). In addition, PSTs need to develop well their subject matter knowledge (Niess, 2005), because the choice of educational technology by pre-service teachers is affected by their level of TPACK (Johnston, 2012). Today’s TPACK framework is an important part of teacher education programs and K-12 teacher professional development (Mishra, Koehler, & Henriksen, 2011). Enochson and Rizza (2009) addressed that PSTs can improve their use of technology experience by creating instructional practices themselves and observing good examples.

There are limited studies of PSTs’ development of TPACK (Ozgun-Koca, Meagher, Edwards, 2009/2010). Powers and Blubaugh (2005) pointed out the importance of teacher education programs. Their university created two methods courses for preparation of preservice teachers to use technology, and gave three examples which presented activities used in these methods course. They stated that if PSTs have successful experiences with technology integration, are familiar with using technology, and feel comfortable with technology, they will successfully and effectively integrate and use technology in their mathematics classrooms. Morrison and Jeffs (2005) found similar result as PSTs’ integration of technology into their
future classroom is affected positively by their experiences in teacher preparation programs. Polly and colleagues (2010) identified a positive impact of methods courses of technology integration and field experience to PSTs’ TPACK. Niess (2005) developed the TPACK in a science and mathematics program in which technology was integrated for teaching and learning. In this program, the author instructed PSTs in how to integrate technology in designing lessons, provided opportunities for PSTs to practice the lessons in the methods course, and required PSTs to teach the lessons during student teaching.

Meagher, Ozgun-Koca and Edwards (2011) used the TPACK model to examine 22 PSTs’ experiences with advanced digital technologies, especially the use of the TI-Nspire but also SmartBoard, websites, and Geometer’s Sketchpad, during the method course. The participants mentioned that the use of graphing calculators allow students to solve tasks in more than one-way. PSTs were required to create four lesson plans, and though the quality of lesson plans improved over the semester, there was not strong evidence of TPACK. In addition, if technology use was required of PSTs, they tended to use technology; when technology use was optional, they did not use the technology. The conclusion of the study was that PSTs’ TPK and TPACK skills were clearly developing during the method course in which they gained more experience with technology skills and increase their thinking about mathematics content and use of technology.

Developing knowledge of TPACK is an important aspect in PSTs’ training, because PSTs can have opportunities to develop their experience and knowledge of how to integrate technology through the method courses. For example, Niess (2006) highlighted the importance of TPACK development in the teacher preparation coursework, because “TPCK is an important
body of knowledge for teaching mathematics, for the importance of integrating its development within the coursework in teaching and learning, as well as within the coursework directed at developing knowledge of mathematics” (p.198). Niess recommended that all teachers and teacher candidates must obtain knowledge and experience for technology integration in teaching and learning mathematics.

In this investigation, PSTs created technology-based instructional activities (i.e., technology activities). The mathematical quality of a technology activity will be measured by the extent of students’ opportunities to engage in thinking and reasoning in the process of learning mathematics. This is referred to as the “level of cognitive demand” (Stein & Lane, 1996). Research in mathematics education has identified that the level of cognitive demand often changes from what was intended by the instructional task, what actually happens during instruction, and what product or student-response is expected by the teacher (Stein & Lane, 1996; Stigler & Hiebert, 2004; Tarr, Reys, Reys, Chavez, Shih, & Osterlind, 2008). The levels of cognitive demand, and how demands can change throughout a lesson, will be described in the following section.

2.6 Instructional Quality in Mathematics

In this investigation, frameworks from mathematics education research are being used to determine whether PSTs can integrate technology into instructional activities in ways that support students’ learning of mathematics. Students’ opportunities to learn mathematics are often assessed by considering the level of cognitive demands of mathematical tasks and the implementation of tasks during mathematics instruction (e.g., Boaler & Staples, 2008; Boston,
A mathematical task is defined as “a classroom activity, the purpose of which is to focus students' attention on a particular mathematical concept, idea, or skill” (Henningsen & Stein, 1997, p. 528). A mathematical task can consist of a single problem or exercise (simple or complex and multi-step) or a set of related problems or exercises that focus students’ attention on a particular mathematical idea (Stein, Smith, Henningsen, & Silver, 2009). For example, the following is an example of multi-step task.

“Ryan, Tom and Jordan collect baseball cards and are getting ready to make some trades. Ryan has 43 cards and Tom has twice as many at Ryan. Jordan has 50 more cards than Ryan and Tom have together. How many cards are available to trade?” (NC Department of Public Instruction, n.d.)

Students need to make sense of problems and then apply multi-step strategies to solve this task. An example of a set of related problems is demonstrated in Figure 2 (https://www.engageny.org/sites/default/files/resource/attachments/g3-m1-full-module.pdf). The question has two sub-questions, and will be considered as one mathematical task.
2. Mrs. Tran picks 15 tomatoes from her garden. She puts 5 tomatoes in each bag.
   a. Draw Mrs. Tran’s bags of tomatoes.
   b. Write and solve a multiplication sentence to describe your drawing in Part (a).

Figure 2. An example of a set of related problems (Engageny, 2013).

Stein, Grover and Henningsen (1996) develop the Mathematical Task Framework to model the phases of a lesson where students might engage in different kinds of thinking while working on mathematical tasks. The Mathematical Task Framework (MTF) is showed in Figure 3 (as represented in Henningsen & Stein, 1997).

Figure 3. Mathematical Task Framework (Henningsen & Stein, 1997).

As modeled by the MTF, mathematical tasks pass through three phases during a lesson: mathematical tasks as written (or represented in curricula), mathematical tasks as set up by teachers, and mathematical tasks as implemented by teachers (and engaged by students). Figure
3 shows the relationship between these phases and factors that influence the set up and implementation of a mathematical task. The “levels of cognitive demands” of a task may be different during each of these three phases. For example, teacher’s knowledge of content and students, and teacher’s goals can affect the set-up of task from how it appeared in written materials. As the lesson progresses between the set-up phase to the implementation phase, teacher’s instructional dispositions, students’ learning dispositions, classroom norms, and task condition can affect students’ learning. In this study, how PSTs select curricular/instructional tasks for their technology activities, how they sets up the technology activities for student engagement, and how students’ implement the mathematics tasks are the main focus.

Task set-up by teachers is defined as teacher’s announcement of the task and/or directions for students to complete the task (Stein, Grover, & Henningsen, 1996). Task implementation is defined as the level of reasoning and thinking in which students actually engage during mathematics instruction. Task implementation has been shown to have the greatest impact on students’ learning (Stein & Lane, 1996; Stigler & Hiebert, 2004; Tarr et al., 2008).

2.6.1 Cognitive Demand of Mathematical Tasks.

Mathematical tasks were differentiated by Stein and her colleagues based on the level of cognitive demands. “Level of cognitive demand” is defined as the level of thinking and reasoning required by students to solve and engage with the task (Stein, Smith, Henningsen, & Silver, 2009). Drawing on the work of Doyle (1988), Stein and colleagues describe two categories of mathematical tasks with high-level cognitive demands (“doing mathematics” tasks and “procedure with connection” tasks) and two categories of mathematical tasks with low-level
cognitive demands (“procedure without connections” tasks and “memorization” tasks), as described in Figure 4.

**Low-Level Cognitive Demand Tasks**

**Memorization:**
- Involve either reproducing previously learned facts, rules, formulas, or definitions or committing facts, rules, formulas or definitions to memory.
- Cannot be solved using procedures because a procedure does not exist or because the time frame in which the task is being completed is too short to use a procedure.
- Are not ambiguous. Such tasks involve the exact reproduction of previously seen material, and what is to be reproduced is clearly and directly stated.
- Have no connection to the concepts or meaning that underlie the facts, rules, formulas, or definitions being learned or reproduced.

**Procedures without Connections:**
- Are algorithmic. Use of the procedure either is specifically called for or is evident from prior instruction, experience, or placement of the task.
- Require limited cognitive demand for successful completion. Little ambiguity exists about what needs to be done and how to do it.
- Have no connection to the concepts or meaning that underlie the procedure being used.
- Are focused on producing correct answers instead of on developing mathematical understanding.
- Require no explanations or explanations that focus solely on describing the procedure that was used.

**High-Level Cognitive Demand Tasks**

**Procedures with Connections:**
- Focus students’ attention on the use of procedures for the purpose of developing deeper levels of understanding of mathematical concepts and ideas.
- Suggest explicitly or implicitly pathways to follow that are broad general procedures that have close connections to underlying conceptual ideas as opposed to narrow algorithms that are opaque with respect to underlying concepts.
- Usually are represented in multiple ways, such as visual diagrams, manipulatives, symbols, and problem situations. Making connections among multiple representations helps develop meaning.
• Require some degree of cognitive effort. Although general procedures may be followed, they cannot be followed mindlessly. Students need to engage with conceptual ideas that underlie the procedures to complete the task successfully and that develop understanding.

**Doing Mathematics:**

• Require complex and nonalgorithmic thinking—a predictable, well-rehearsed approach or pathway is not explicitly suggested by the task, task instructions, or a worked-out example.
• Require students to explore and understand the nature of mathematical concepts, processes, or relationships.
• Demand self-monitoring or self-regulation of one’s own cognitive processes.
• Require students to access relevant knowledge and experiences and make appropriate use of them in working through the task.
• Require students to analyze the task and actively examine task constraints that may limit possible solution strategies and solutions.
• Require considerable cognitive effort and may involve some level of anxiety for the student because of the unpredictable nature of the solution process required.

*Figure 4. The Task Analysis Guide (Stein, Smith, Henningsen, & Silver, 2009)*

The selection of a high-level mathematics tasks for a lesson does not guarantee high-level thinking opportunities for students throughout the lesson (Boston & Smith, 2009). As modeled in the MTF, the level of cognitive demands of the mathematics task could change during implementation as teachers and students interact with tasks during instruction (Stein, Grover and Henningsen, 1996). Stein et al. (2009) note that the set-up phase and implementation phase impact student learning. The implementation phase is especially important, because students work on the task during task implementation. Henningsen and Stein (1997) highlight the difficulties of maintaining high-level demands during implementation and how that affects students’ engagement in high levels of cognitive processing.
For example, Stein and Lane (1996) studied the effects of cognitive demands of mathematics tasks both during the set up phase and the implementation phase on student learning. Their focus was to determine the correlation between student learning and the cognitive demands of the mathematical tasks. They observed instruction at four schools and developed an instrument to measure students’ learning. The instructional tasks in three schools tended to start with high-level cognitive demands; however only one school maintained high-level cognitive demands during implementation, and the level of cognitive demands at two schools consistently declined. The instructional tasks at fourth schools tended to start with low-level tasks. They found a relationship between students’ learning and thinking and the use of instructional tasks. If students engage with high-level mathematical tasks, they gain greater learning. They conclude, “the nature and level of instructional tasks used in the classroom have a substantial impact on student thinking which, in turn, affects student performance and learning” (p. 74).

After clearly identifying learning goals, mathematical tasks should be selected or created to suit these learning goals, and cognitive demands of the tasks must be a key focus of attention (Stein, Smith, Henningsen, & Silver, 2009), since students work on tasks during the majority of their time in mathematics class (Boston & Smith, 2009). Stein, Grover, and Henningsen (1996) highlighted importance of tasks and the effects on students learning:

The mathematics tasks with which students become engaged determine not only what substance they learn but also how they come to think about, develop, use and make sense of mathematics. Indeed, an important distinction that permeates research on academic tasks is the differences between tasks that engage students at a surface level and tasks that
engage students at a deeper level by demanding interpretation, flexibility, the shepherding of resources, and the construction of meaning (p.459).

Stein, Grover, & Henningsen, (1996, p.16) identified factors that associated with the decline and maintenance of high-level cognitive demands. Figure 5 presents these factors. In this study, the factors associated with the maintenance and decline of high-level cognitive demands form the basis of the rubrics that will be used to evaluate the implementation of PSTs’ technologies activities and students’ work.

<table>
<thead>
<tr>
<th>Factors Associated With the Decline of High-Level Cognitive Demands</th>
<th>Factors Associated With the Maintenance of High-Level Cognitive Demands</th>
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</table>
| 1. Problematic aspects of the task become routinized (e.g., students press the teacher to reduce the complexity of the task by specifying explicit procedures or steps to perform; the teacher “takes over” the thinking and reasoning and tells students how to do the problem).  
2. The teacher shifts the emphasis from meaning, concepts, or understanding to the correctness or completeness of the answer.  
3. Not enough time is provided to wrestle with the demanding aspects of the task or too much time is allowed and students drift into off-task behavior.  
4. Classroom management problems prevent sustained engagement in high-level cognitive activities.  
5. Inappropriateness of tasks for a given group of students (e.g., students do not engage in high-level cognitive activities due to lack of interest, motivation or prior knowledge needed to perform; task expectations not clear enough to put students in the right cognitive space).  
6. Students are not held accountable for high-level products or processes (e.g., although asked to explain their thinking, unclear or incorrect student explanations are accepted; students are given the impression that their work will not “count” toward a grade). | 1. Scaffolding of students’ thinking and reasoning.  
2. Students are provided with means of monitoring their own progress.  
3. Teacher or capable students model high-level performance.  
4. Sustained press for justifications, explanations, and/or meaning through teacher questioning, comments, and/or feedback.  
5. Tasks build on students’ prior knowledge.  
6. Teacher draws frequent conceptual connections.  
7. Sufficient time to explore (not too little, not too much). |
Figure 5. Factors associated with the decline and maintenance of high-level cognitive demands (Stein, Grover, & Henningsen, 1996, p. 16).

Teachers need to select high-level tasks and maintain these tasks during the implementation to provide opportunities for students to understand mathematics and connect mathematical ideas (Boston & Smith, 2009). This process begins in lesson planning and how teachers use curriculum.

2.6.2 Curriculum Use and Lesson Planning.

Stein, Remillard, and Smith (2007) described curriculum as what is taught and experienced in the classroom. Curriculum, especially standard-based curriculum, is designed materials for teachers to use in the classroom, and they defined three types of curriculum: written, intended, and enacted curriculum. For intended curriculum, set of objectives, goals, and specific purposes are set at the beginning of the curricular plan. Written curriculum refers to what the curricular makers want teachers and students to do in the classroom. Intended curriculum represents what the teacher plans to do in the classroom (lesson plans, school-based curriculum guides, etc.). Enacted curriculum refers to what is actually taught and learned in the classroom. Figure 6 shows the phases of curriculum use (note the similarities to the MTF, Figure 3).
Lesson plans are part of the intended curricula, and teacher thinking about how lessons should be taught can be reflected in lesson plans (Remillard, 1999; Stein, Remillard, & Smith, 2007). Teachers are encouraged to integrate technology in their classroom, and also into lesson plans (Jones, 2001), because the ability of creating lesson plan is an important element for teaching (Choy, 2014): “It is important that teachers are able to develop well-conceived lesson plans that are structured and detailed, focusing on specific mathematics topics and using multiple representations” (p.256).

Every teacher must consider designing good lesson plan, because it helps teachers to navigate the teaching during the class time. Planning a lesson is a core skill, but it is still challenging for some teachers. Especially for beginning teachers, it is hard to think of what questions will be asked, selecting teaching models and instructional activities, how to present concepts accurately (Choy, 2014), and how to guide students during the lecture. In this study, PSTs will plan mathematics instructional activities that integrate technology.

2.6.3 Measuring instructional quality in mathematics

“School districts across the country are struggling to improve the quality of instruction” (p.268), and several resources are provided for teachers to help them to teach well (Matsumura,
Garnier, Slater & Boston, 2008). Boston and Smith (2011) stated the importance of assessments of instructional quality at the school and classroom level based on classroom activities to increase and recognize the quality of education for all students. Data for measuring the quality of instruction can be obtained from classroom observation, survey, case studies, or self-report. Conducting a survey and/or self-report are less expensive; and surveys can be used effectively to measure teachers’ content knowledge for teaching (e.g., Hill, Rowan, & Ball, 2005) and teachers’ beliefs about teaching. Observation is one way to measure the quality of instruction, but it takes time and also is expensive (Matsumura, Garnier, Pascal, & Valdes, 2002). Observation can be used to determine teachers’ instructional practices and what teachers and students are doing in the classroom in the process of teaching and learning mathematics.

According to Boston (2012), “the use of classroom artifacts to assess instructional quality provides a methodology that may be more feasible than classroom observation, facilitating classroom research for both large- and small-scale studies or for research in classrooms or schools that are not amenable to observations (p.79). Classroom artifacts (e.g., tasks, lessons plans, samples of students’ work) also can be used to assess the quality of instruction because they provide a ‘snap shot’ of instruction. Matsumura et al. (2008) identified a high correlation between student work and observed instruction, and stated that student work is a statistically stable proxy for observed instruction. In addition, Boston (2012) mentioned, “student work may provide a correlated yet different picture of instruction, indicating a higher quality of instruction than lesson observations” (p. 97).
2.6.4 Technology use and mathematical tasks.

Previous research has examined the connection between technology-based instructional tasks and level of cognitive demand of mathematics tasks. Polly (2014) investigated what types of mathematical tasks teachers pose while using technology in elementary mathematics education, and stated that there is a relationship between mathematical tasks and use of technologies. He observed three teachers, and he observed each teacher between 25 and 30 times. He analyzed total of 504 mathematical tasks during the school year. He found that 210 of these tasks (72 memorization and 138 procedures without connection) had low-level cognitive demands, and 294 had high-level cognitive demands (277 procedures with connection and 17 doing mathematics). The projector and document camera to display mathematical tasks or student work examples were used in every lesson. However, the desktop computer was only observed in eight lessons, and Ipad was used 14 times by teachers. While Ipad technology was used, most of the mathematical tasks were observed as low-level tasks; especially, types of memorization with one-step questions, and for other technologies a mix of low-level and high-level tasks were observed.

Johnson (2009) studied the roles of technology integration in mathematics lesson plans from PSTs in elementary mathematics education. He collected data from 35 pre-service elementary mathematics teachers and analyzed lesson plans and reflection documents that pre-service teachers created. To identify PSTs’ roles of how technology was integrated, Johnson used a framework from Goos, Galbraith, Renshaw, and Geiger (2000; 2003). Goos, and colleagues (2000; 2003) classified PSTs’ use of technology into the following categories:
- Technology as master: “Teachers and students may be subservient to the technology if their knowledge and usage are limited to a narrow range of operations over which they have technical competence” (Goos, et al., 2003, p.77).

- Technology as servant: Teachers integrate technology to support teaching methods. Teachers do not need to incorporate new teaching strategies.

- Technology as partner: The role of technology is to support and extend student learning. Students are more active “rather than passive transmission of information” (Johnston & Suh, 2009, p.3562) and control their learning.

- Technology as extension of self: As the highest-level role of technology, “technology as extension of self” is rarely present in practice. “Writing courseware to support and enhance an integrated teaching program would be an example of operating at this level” (Goos, et al., 2000, p.308).

Johnston (2009) extended Goos and colleagues’ framework to include three new roles that emerged during his analysis of technology-use in elementary mathematics PSTs’ lesson plans and reflection documents: Technology Not Used (TNU; including sub-roles of TNU-Willing and TNU-Master), and combined roles of Master-Servant and Servant-Partner, where PSTs exhibited beliefs and actions characteristics of multiple roles. Johnson did not identify PSTs taking on the roles of “technology as partner” or “technology as extension of self” in his study. Johnson explains the “technology not used” role as follows:

Technology Not Used (TNU): “…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.” (p. 72).

Mathematics lesson plans in which technology was used were categorized in four types based on lesson plan design: display/demonstration, student exploration, review and practice, and productivity. Display (64.3%) was the most commonly observed design, then student exploration (17.9%), review and practice (14.3%), and productivity (3.6%). 15 of 35 PSTs selected SmartBoard technology, which was the most often used and selected technology while planning for mathematics instruction, because SmartBoard technology is available in the classrooms. Six PSTs stated that they were not able to use technology while planning a lesson, because of “cooperating teacher constraints, classroom technology constraints, or for other reasons” (Johnston, 2012, p.136). Only one PST used calculators, and only one PST used cell phones in mathematics lesson plans. PSTs in the study aimed to use existing technological tools and mathematical tasks. Johnson (2009) concluded that the majority of PSTs planned lessons that used technology in limited ways and did not engage students in high-level thinking and reasoning (e.g., using technology for display or review and practice).

Sherman (2011) studied teachers’ use of technology in relation to the level of cognitive demand, and how use of technology affected the cognitive demands of mathematics tasks during the set-up and implementation phases of a lesson. Teachers’ use of technology was grouped into
two main types: 1) an amplifier (“technology allows for more efficient execution of by-hand procedures”) and 2) a reorganizer (“technology has the potential to change the cognitive focus of the task, for example, by giving students access to mathematical concepts, representations, or behaviors that might otherwise be difficult or impossible”) (p.121). A total of 63 tasks were observed related to whether or not technology is used as part of the task in four teachers’ classrooms.

He observed and interviewed four secondary mathematics teachers and collected samples of students’ works. All teachers were third year teachers. Three of them taught high school, and one of them taught 6th grade. Technology use in relation to the cognitive demand in curricular materials included 63 tasks in set up and implementation phases. However, some of the 63 tasks did not use technology, and teachers used tasks that did not appear in curricular materials. In reporting results, he considered the cognitive demand of tasks that used technology in 1) curricular materials and 2) as set up and implemented by teachers. In curricular materials, 13 of 29 tasks (44.8%) had high-level demands. In the “potential of the task” phase, 23 of 48 tasks using technology (47.9%) had high-level demands. For the “task implementation” phase, only 7 out of 56 tasks (12.5%) were enacted at a high-level throughout the lesson. In this study, tasks that included technology were consistently implemented at a low level (Sherman, 2011).

During the set up and implementation phases, low-level mathematical tasks were used when technology is used as an amplifier. Technology as an amplifier “generally had little or no influence on the cognitive demand of the task (Sherman, 2011; p.292). Technology used as an amplifier did not pose additional thinking requirements on the tasks (and hence did not change the cognitive demand of the original task). However, high-level thinking requirements were
incorporated into the task when technology was used as a reorganizer or when technology was used as both reorganizer and amplifier.

Schultz (2009) conducted a qualitative case study to determine how teachers select and implement mathematics tasks with a particular focus on using technology during instruction. She observed three high school teachers and identified how technology can affect the cognitive demand of a mathematics task: “(a) assessing the mathematical context of a task to determine the appropriateness of technology use as a solution strategy and (b) translating between the mathematical and technological contexts of the task” (p. 117). The first teacher selected tasks with low-level cognitive demands (especially procedures without connections). For example, he used low-level tasks to introduce new topics, however high-level tasks were selected for homework or exploration. For implementation, he used high-level cognitive demands tasks “by asking students to consider multiple representations of a particular solution, demanding detailed interpretations of how the mathematics in a particular task related to its real-world context, and extending the mathematics in the task to novel situations “ (p.115). The second teacher selected a balance between low and high-level tasks, and she maintained the cognitive demands of the tasks during implementation. The third teacher selected low level tasks (especially procedures without connection) and they also resulted in low-level cognitive demands during implementation.

2.7 Summary

The majority of studies of the effects of using technology on the cognitive demands of mathematics tasks have some similarities and differences. Table 1 demonstrates a comparison of these studies. For example, Johnston (2009) focused on how technology was used in mathematics lesson plans by PSTs and roles between PSTs and technology integration in
mathematics lesson plan designs. However, he did not focus on how technology influences students’ learning and thinking. In this present study, the researcher focuses on the cognitive demands of the mathematics tasks in PSTs’ technology activities and thereby investigates how technology supports students learning and thinking in mathematics.

Table 1

Summary of Studies on Technology Use and Mathematical Tasks

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<tr>
<td><strong>Sample</strong></td>
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<td>Elementary school teachers in math</td>
<td>High School teacher</td>
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<td>Mathematical Tasks Framework</td>
<td>Mathematical Tasks Framework</td>
<td>Mathematical Tasks Framework</td>
</tr>
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<td><strong>Technology</strong></td>
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<td>Amplifier or Reorganizer</td>
<td>Desktop computer, Ipads, document camera, projector, Smartboard</td>
<td>No information</td>
</tr>
<tr>
<td><strong>Data</strong></td>
<td>Pre-Service Elementary Mathematics Teachers’ Self-Reported Content Knowledge &amp; Technology Preparation Survey, Observation, Interview</td>
<td>Observation, Interview</td>
<td>Observation, Interview</td>
<td>One preceding and one following the observation period, and interview</td>
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2.8 Conclusion

Previously, pedagogy and content knowledge were focused on as components of PSTs’ preparation programs, but today’s mathematics teacher educators must focus on knowledge of technology, content, and pedagogy together. Specifically, we must educate prospective teachers about how to use technology to transform teaching practices in specific subject matters. PSTs can have opportunities to improve their knowledge of TPACK when developing lesson activities for method courses in which they design lesson plans through considering content, pedagogy, and technology. They can gain experience using technology, and they can apply in their future classroom what they learned during the teacher preparation program.

Sullivan, Clarke, ad Clarke (2013) described a set of variables influencing implementation of tasks by teachers, including: teacher subject matter knowledge and pedagogical content knowledge, teacher beliefs about mathematics, teacher attitudes to mathematics, teacher self-goals, teacher experience, and how teacher plan to teach. It is important what teachers know about choosing and using tasks and technology for teaching and learning, because their knowledge and implementation of these tasks and technology are connected to each other and because using technology shapes the type of students’ learning. Understanding the interaction of PSTs knowledge of technology, use of technology in
instruction, and selection of mathematics tasks are considered in this study, because these factors are important for instructional quality. A description of the methodology is presented in the following chapter to accomplish the research purposes.
CHAPTER III

METHOD

The purpose of this study is to determine pre-service teachers’ (PST) ability to integrate technological tools into instructional activities in mathematics in ways that support students’ high-level thinking and reasoning. In addition, the study also examines PSTs’ level of technology implementation and how PSTs’ level of technology implementation is related to their ability to integrate technological tools into instructional activities in mathematics. The results of this study may contribute to the development of mathematics teacher-preparation programs that prepare future teachers with high quality skills in integrating technology to improve and support students’ learning of mathematics. The following research questions will be addressed in this study:

Research Question One (RQ1):

- What are the cognitive demands of instructional activities when pre-service mathematics teachers are asked to integrate technology into mathematics lesson activities: a) created for an assignment during the mathematics methods course; and b) created and used during student teaching?

a) What is the level of cognitive demand of the instructional tasks created or selected by PSTs in technology activities for: 1) an assignment in a mathematics methods course, and 2) during student teaching?
b) What is the level of cognitive demand of the implementation of the instructional tasks as described in the technology activities created by PSTs for: 1) an assignment in a mathematics methods course, and 2) during student teaching?

c) What is the level of expected student responses in the technology activities created by PSTs for: 1) an assignment in a mathematics methods course, and 2) during student teaching?

d) Are there differences between the level of cognitive demand of the instructional tasks, implementation of the instructional tasks as described, and of expected student responses in the technology activities created or selected by PSTs for an assignment in a mathematics methods course?

e) Are there differences in the level of cognitive demand of the instructional tasks, implementation of the instructional tasks as described, and of expected student responses in the technology activities created or selected by PSTs for an assignment in a mathematics methods course by each grade level?

f) Does the level of cognitive demand of the instructional tasks, implementation of the instructional tasks as described, and of expected student responses in the technology activities created or selected by secondary level PSTs for an assignment differ from the level of cognitive demand of the instructional tasks, implementation of the instructional tasks as described, and of expected student responses in the technology activities created or selected by secondary level PSTs for student teaching?

Research Question Two (RQ2):

- What is the mathematics pre-service teachers’ level of technology integration?
a) Are there any differences in the mathematics pre-service teachers’ level of technology integration by grade level?

Research Question Three (RQ3):

- How is PSTs’ level of technology integration (RQ2) related to the level of cognitive demand of instructional tasks in PSTs’ mathematics lesson activities that integrate technology (RQ1)?

A pilot study served as a precursor to this dissertation. In Fall 2013, 30 technology activities from 26 PSTs were analyzed. Data on PSTs’ level of technology integration (RQ2) has not been included in the pilot study. The researcher examined how technology tools would be used by PSTs when planning for instruction, and how the use of technology tools supported or encouraged students’ engagement in cognitively demanding mathematical work and thinking. The results of the pilot study provided a better understanding of how to analyze PSTs’ technology activities. The pilot study was also helpful in refining and improving Research Question 2 and the research methods of this dissertation.

3.1 Subjects

All pre-service teachers (PST) in the PK-4 program, Middle Level program (grades 4-6) and Secondary Mathematics (grades 7-12) program during the 2014-2015 school year at a mid-sized private university in the northeastern United States were asked to participate in this study. A convenience sample selection, which is a type of non-probability or opportunity sample technique, was used in this study. PSTs at the given university are a convenient source of subjects for this study and can provide data aligned with the research aim and purpose. As
Teddlie and Yu (2007) state, “convenience sampling involves drawing samples that are both easily accessible and willing to participate in a study” (p.78).

PSTs were asked permission for the researcher to use as data for this study their instructional activities: 1) created for an assignment during the mathematics methods course, and 2) created and used during student teaching. First, PSTs were asked permission by the course instructor to provide the researcher with copies of technology-based instructional activities they created as part of their assigned coursework for the mathematics pedagogy courses (e.g., PK-4 Numeracy Pedagogy, Teaching Mathematics Grades 4-8, Teaching Secondary Mathematics). The course instructors were not made aware of who decided to participate until after the grades had been finalized for the semester. Course instructors were asked to retain copies of the technology assignments submitted by all students in the course. After grades had been finalized for the semester, the researcher then provided the instructor the participants’ names and only assignments from those students were copied by the researcher.

Second, for their student teaching “Showcase” portfolio, all PSTs were required to submit instructional activities and samples of students’ work (with students’ names removed). Showcase portfolios for secondary mathematics PSTs were submitted to instructor at the end of the student teaching placement, and must contain a technology-based instructional activity. PSTs were asked to allow the researcher to use copies of the technology activities and students work (with students’ name removed) from the student teaching Showcase Portfolio. Student teaching typically occurs 1-2 semesters after the mathematics pedagogy course. For students who choose to participate, these documents were provided to the researcher (doctoral candidate) by the instructor.
PSTs in the PK-4 and Middle Level program were not required to submit a technology-based instructional activity in their student teaching portfolio, and the researcher requested that PK-4 and Middle Level PSTs integrate technological tools into an instructional activity in their student teaching portfolio. If the PK-4 and Middle Level PSTs did not include a technology-based technology activity and samples of student work in their student teaching portfolio, the researcher only used their instructional activities created for the methods course.

3.2 Context of the Course and Technology Plan

As described, the PSTs in this study were enrolled in a mathematics methods course entitled “Numeracy Pedagogy PK-4,” “Teaching Middle Level Mathematics,” or “Teaching Secondary Mathematics” in Fall 2014 and Spring 2015. At its core, each course was organized around: 1) a developmental, social-constructivist view of teaching and learning mathematics, using texts such as, “Teaching Student-Centered Mathematics - Grades 5-8” (Van de Walle & Lovin, 2005) and “Elementary and Middle School Mathematics: Teaching Developmentally” (Van de Walle, Karp, & Bay-Williams, 2007); and 2) a task-focused approach to lessons planning, instruction, and reflection; using tools and frameworks from “Implementing Standards-Based Mathematics Instruction: A Casebook for Professional Development” (Stein, Smith, Henningsen, & Silver, 2009), the “Thinking through a Lesson Protocol” (Smith, Bill, & Hughes, 2008), and “5 Practices for Orchestrating Productive Mathematics Discussions” (Smith & Stein, 2011). As such, each course has a strong focus on selecting and implementing cognitively challenging mathematical tasks. PSTs learn to identify cognitive demands by engaging in a “Task Sort” (Smith, Stein, Arbaugh, Brown, & Mossgrove, 2004), analyzing curricula, and justifying the level of cognitive demand for instructional tasks used during the course and in their
own lesson plans. PSTs also consider ways of implementing cognitively demanding tasks by analyzing written and video cases of mathematics instruction and samples of student work, through rehearsals of teaching (Grossman & McDonald, 2008) during the course, and by presenting at least one mathematics lesson to K-12 students during the field placement that accompanies each specific course.

In the “Numeracy Pedagogy” course, PSTs investigate the teaching and learning of mathematics in grades PK-4. PSTs produce lesson plans for whole number operations, fractions, and geometry at specified grade levels. PSTs are asked to create technology activities for grades PK-4 in the content areas of algebraic thinking and data or probability.

In the Middle Level course, pair/groups of 2-3 PSTs plan a unit of instruction (e.g., a series of consecutive lessons around a specific mathematical topic), consisting of an overview and trajectory of the mathematical ideas in the unit, three complete lesson plans per person, assessments, literature connections and other activities to engage middle school students, and technology-based instructional activities. The purpose of asking PSTs to find or create technology activities is to provide opportunities for PSTs to integrate instructional technology into specific mathematical content.

In the “Teaching Secondary Mathematics Course,” PSTs investigate curricula and plan lessons in algebra, geometry, trigonometry, statistics, or calculus. Each PST creates three lesson plans: 1) algebra, 2) geometry, and 3) a higher-level mathematics course. PSTs are asked to plan technology activities that address important mathematical content at the high school level; that is, in Algebra I and beyond.
In each course, the “Technology Assignment” occurs toward the end of the semester. Each pair/group submits a collection of three technology tasks that must contain the use of the interactive whiteboard (e.g., SmartBoard), graphing calculator, and an Internet resource in ways that support students’ learning of the mathematical ideas in the unit. The Technology Assignment and rubric are provided in Appendix M. Note that the Technology Assignment does not specifically indicate that PSTs should select or create a cognitively challenging instructional task. PSTs are asked to incorporate specific types of instructional technology tools (e.g., SmartBoard, graphing calculator, internet) and to use technology to teach mathematical content aligned with the specific grade-levels of the course.

3.3 Data Sources

The setting for this research is a mid-size private university located in the northeastern US. The sources for data collection include pre-service teachers’ technology activities for the mathematics method courses and student teaching, and a survey. The PSTs were asked to: 1) provide the technology activities from the mathematics pedagogy course; 2) share materials from the Student Teaching Showcase portfolio (e.g., copies of technology activities used while student teaching, and samples of students work from those activities); and 3) complete the “Levels of Teaching Innovation (LoTi) Digital Age Survey”.

3.4 Instruments

In this study, the Levels of Teaching Innovation (LoTi) Digital Age Survey (Learning Quest, 2011) was used to collect data from PSTs about their Personal Computer Use (PCU), Current Instructional Practices (CIP), Level of Technology Implementation (LoTi). Technology
activities were analyzed using the Instructional Quality Assessment (IQA) Mathematics rubrics (Boston, 2012). The following section will give information about the survey instrument and IQA Mathematics Rubrics.

### 3.4.1 Instructional Quality Assessment (IQA) in mathematics rubrics.

To assess PSTs’ ability to integrate technology into mathematics lesson activities (RQ1), technology-based instructional tasks and samples of student work were collected and analyzed using the Instructional Quality Assessment in Mathematics (IQA) rubrics (Boston, 2012; Appendices A, B, C) to determine the level of cognitive demand of the instructional task and the level of cognitive process engaged in by students as they worked on the task. The IQA Toolkit contains about 20 rubrics to measure the quality of instruction and learning in English /Language Art and Mathematics using lesson observations and students’ work (Boston & Wolf, 2006). These rubrics have been tested for reliability and validity in elementary and secondary mathematics classrooms (Boston, 2012; Matsumura at el., 2008). In Matsumura and colleagues (2008), inter-rater agreement was used to determine the reliability of IQA. Three raters independently coded each of the assignments, and exact scale-point agreement in mathematics overall was 76% with exact scale-point agreement for the individual mathematics rubrics’ ranging from 63% to 85%. While Boston and Wolf (2006) identified lower inter-rater reliability for IQA AR-Math Rubrics for Assignment (e.g., ranging from 60 % to 67.3%) with newly trained raters, Boston and Smith (2009) identified higher exact-point agreement (e.g., ranging from 86.7% to 93.3%) with expert raters (e.g., mathematics education researchers and doctoral students).
“The Instructional Quality Assessment (IQA) Toolkit was designed to provide statistical and descriptive data about the nature of instruction and students’ opportunities to learn” (Boston, 2012, p. 5). IQA rubrics were developed based on the Levels of Cognitive Demand and the Mathematical Tasks Framework described in Chapter 2. In this study, the IQA Mathematics rubrics will be used to measure the instructional quality of technology-based instructional activities based on three indicators: instructional task as written, task implementation, and expected student responses. Data in PSTs’ technology activities will be scored using the Instructional Quality Assessment (IQA) Academic Rigor (AR) in Mathematics rubrics for Potential of the Task, Described Implementation, and Expected Student Responses.

**Potential of the Task.** The cognitive demand of the mathematical task as it appears (i.e., as written or on screen) in the technology activity is coded as The Potential of the Task. The original IQA Academic Rigor 1 (AR1) rubric will be used to code each task. The researcher coded Potential of the Task as “did the task have potential to engage students in rigorous thinking about challenging content?”

**Described Implementation.** Task implementation is described as the level at which the teacher supports students to engage with the task throughout the lesson, or how tasks are enacted during instruction. For data from PSTs’ student teaching (e.g., instructional activities and student work), the cognitive process evidence in students’ written work will be scored for Task Implementation using the IQA Mathematics Assignments-Academic Rigor rubric for Implementation (AR2). For data from the methods courses, PSTs’ technology activities will be coded for “Described Implementation” based on the description of how the PST aims to use the technology tasks in the instructional activity. The rubric for Described Implementation was
modified from the original IQA Mathematics Academic Rigor-Implementation rubric (AR2) and was tested during the pilot study and another study of cyber-based curriculum.

**Expected Student Responses.** Expected student response is the extent to which students show their work and explain their thinking about the important mathematical content. The Expected Student Response rubric was modified from the original Academic Rigor 3 (AR3) Elaborates of Student Responses rubrics in the IQA Mathematics Assignments rubrics, and tested in the pilot study. The modified rubric will be used to score “expected students’ responses” in PSTs’ technology activities from the methods courses. The original “Elaborates of Student Responses” rubric will be used to score samples of students’ work from PSTs’ student teaching lesson activities.

### 3.4.2 Levels of Teaching Innovation (LoTi) Digital Age Survey.

The assessment instrument used to identify PSTs’ levels of technology implementation in this research study (RQ2 and RQ3) is the Levels of Teaching Innovation (LoTi) Digital Age Survey. The Levels of Technology Implementation Framework was first conceptualized in 1994, developed by Dr. Christopher Moersch in 2002 (Learning Quest, 2011), and updated by Moersch (2010). Levels of Technology Implementation Questionnaire (LoTiQ) or Levels of Teaching Innovation (LoTi) Digital Age Survey was developed based on the Levels of Technology Implementation Framework. The purpose of the LoTi Digital-Age Survey is to determine teachers’, administrators’, technology specialists’, etc., implementation of technology (Lemonie, 2007) and “to capture classroom teachers’ digital-age literacy in keeping with the National Educational Technology Standards for Teachers (NETS-T)” (Stolzfus, 2006). The aim of creating LoTi Digital-Age Survey was to evaluate classroom practices and their connections to
higher order thinking skills when technology is implemented in teaching and learning (Learning Quest, 2003). The purpose of using the LoTi Digital-Age Survey in this study is to determine level of pre-service mathematics teachers’ Personal Computer Use (PCU), Current Instructional Practices (CIP), and Level of Technology Implementation (LoTi). The use of the Levels of Teaching Innovation (LoTi) Digital Age Survey in this study was funded by a Student Research Grant from Duquesne University. The researcher obtained permission to use the LoTi Digital-Age Survey from the Levels of Teaching Innovation (LoTi) Digital Age Survey developers (F. Saunders, personal communication) (Appendix I).

The LoTi Digital-Age Survey is a validated tool that has been used in over 40 dissertations in previous years (Mireles, 2012). The internal consistency reliabilities of the LoTi Digital-Age Survey were measured using the Cronbach’s Alpha Test, with $\alpha = .870$. According to George and Mallery (2003), Cronbach’s alpha greater than .9 is “excellent” and greater than .8 is “good” (p. 231). Generally, Cronbach’s alpha of .8 or preferably higher is reasonable (Gliem & Gliem, 2003).

There are six available versions of LoTi Digital-Age Survey: Pre-service Teacher, In-service Teacher, Instructional Specialist, Media Specialist, Administrator, and Higher Education Faculty. This survey is designed to help researchers identify teachers’ level of technology implementation. The original LoTi Digital-Age Survey contains 37 self-report items and takes approximately 20 to 25 minutes to complete. The LoTi Digital-Age Survey questions are based on The National Educational Technology Standards for Teachers (NETS-T) (Learning Quest, 2011).
Based on the research aim of this specific investigation, demographic questions, and additional custom questions have been added, resulting in approximately 45 survey items. The demographic questions were included at the end of the LoTi Digital-Age Survey and contain such items as age, gender, grade level of the technology activity assignment, and grade level of the student teaching placement. Table 2 provides a list of the independent variables that were represented in the demographic questions.

Table 2

*Independent Variable*

<table>
<thead>
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<th>Variable</th>
<th>Measurement</th>
</tr>
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| Grade Level Teaching    | • Elementary School  
|                         | • Middle School    
|                         | • Secondary School |

The LoTi Digital-Age Survey measures three primary indicators: Current Instructional Practices (CIP), Personal Computer Usage (PCU), and Levels of Teaching Implementation (LoTi). The formal reliability for CIP, PCU, and LoTi were establish in 2000 using Cronbach’s alpha to measure internal consistency. Cronbach’s alpha on CIP is \( r = .7353 \), on PCU is \( r = .8148 \), and LoTi is \( r = .7427 \). In addition, Lemoine (2007) established internal consistency using Cronbach’s alpha in her dissertation \( (n=365) \): CIP \( r = .737 \); PCU \( r = .767 \), and LoTi \( r = .917 \). Each indicator is described in the following paragraphs. This research study established internal consistency using Cronbach’s alpha on the LoTi, PCU, and CIP components at \( r = .911, .769, \) and .667 respectively.
Current Instructional Practices (CIP). The CIP indicator (Appendix F) measures the teachers’ or PSTs’ current instructional practice (methods the teacher or PSTs use to deliver instruction) to support a student-centered learning environment. The CIP offers eight response options, and the LoTi Survey uses a Likert scale ranking from 0 to 7. The “0” is used to mark a “Not True of Me Now” and level 7 indicates “Very True of Me Now”. Levels 0-4 focus on “teacher-directed instruction of subject-based material”, and levels 5-7 are “indicative of a more learner-centered instructional approach and student-driven questions and problems” (Berkeley-Jones, 2012; p. 62).

Personal Computer Usage (PCU). The aim of PCU indicator (Appendix E) is to determine teachers’ level of using digital resources and tools to direct student learning and teachers’ proficiency level of computer use. The PCU also offers eight response options ranking from 0 to 7: 0 (Never), 1 (At Least Once a Year), 2 (At Least Once a Semester), 3 (At Least Once a Month), 4 (A Few Times a Month), 5 (At Least Once a Week), 6 (A Few Times a Week), and 7 (At Least Once a Day).

Levels of Teaching Implementation (LoTi). A LoTi indicator (Appendix D) measures teachers’ implementation of instructional technological tools in the classroom settings. The LoTi scale ranking is from 0 to 6. Level 0 indicates “Non-use and perceived lack of access or time” and level 6 indicates “Refinement”.

The LoTi Digital-Age Survey Calculation Key (Appendix G) can be used to score each participant’s LoTi Digital-Age Survey total score. The calculation of overall score for each participant will be discussed under the section “3.5.2 Coding the LoTi Digital-Age Survey”.

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3.5 Coding

In this investigation, the researcher analyzed the technology activities created by PSTs for method courses and the student teaching portfolio to determine whether the PSTs selected or created the technology activities that would support students’ mathematical thinking and reasoning. The researcher also analyzed survey results to determine PSTs’ level of technology use.

3.5.1 Coding of technology-based instructional activities and student work.

Each technology lesson activity was scored using the IQA mathematics rubrics on a scale of 0-4 in three dimensions (Potential of the Task, Description of Implementation, and Expected Student Response). Each lesson activity received one set of scores and was considered to contain one instructional “task,” using the definition of mathematical task offered by Stein et al. (2000): “a segment of classroom activity devoted to the development of a mathematical idea” (p. 7). A mathematical task can consist of a single problem or set of related problems designed to engage students in exploring a mathematical concept and idea (Stein et al., 2009). Hence, though a technology activity might contain more than one mathematical problem, it was considered as containing one “task,” and the activity is given one set of scores for Potential of the Task, Description of Implementation, and Expected Student Response.

The cognitive demand of tasks in PSTs’ technology activities were assessed in three dimensions that reflect different stages of the Mathematics Task Framework (Figure 3): instructional tasks as written (i.e., the technology-based task created or selected by the PST), task as implemented (i.e., how the PST aimed to integrate the task into the lesson activities), and the
expected student response (i.e., as another indicator of implementation, what students are asked to produce by engaging with the task). The purpose of scoring the technology activities in each dimension was to identify whether the cognitive demands of the instructional task changes during the instruction and student responses. This information helps determine whether PSTs can incorporate technology into lessons in ways that supports students’ engagement in cognitively challenging mathematical work and thinking.

**Potential of the Task.** The level of cognitive demands (Stein, Grover, & Henningsen, 1996) can be assessed by the IQA AR1 Potential of the Task dimension (Boston & Wolf, 2006). Tasks can be coded as score level 0 (no mathematical activity), score level 1 (memorization), score level 2 (procedures without connections), score level 3 (procedures with connections or doing mathematics) and score level 4 (procedures with connections or doing mathematics) within lesson activities. The difference is between level 3 and 4 is that the tasks at level 4 explicitly request an explanation, but the tasks at level 3 do not require explanation. Scores of 0, 1, and 2 represent low-level cognitive demands, and scores of 3 and 4 represent high-level cognitive demands (see Figure 7). Hence, “an important demarcation line exists between score levels 2 and 3 that separates high- and low- level cognitive demands in each dimension of the AR- Math rubrics” (Boston & Wolf, 2006, p.12).
Figure 7. Coding for cognitive demand of the task as written, task implementation, and expected student responses.

**Implementation and Described Implementation.** Score levels for Implementation were also scored based on the levels of cognitive demand (Figure 7). For technology activities from the student teaching portfolios, the Implementation score indicates the level of cognitive demand actually engaged in by students during the lesson, as evident in students’ written work. Similarly, for the methods course assignments, Described Implementation indicates the level of cognitive demand of the technology activity based on how the PST describes using the technology task in the instructional activity. Score levels for Implementation and Described Implementation are based on the IQA AR2 Implementation rubric, and parallel the score levels of the IQA AR1 Potential of the Task rubric: no mathematical activity is scored as 0; memorization is scored as 1;
procedural or procedures without connections is scored as 2; engaging in complex thinking or reasoning, or create meaning for mathematical procedures, without producing explanations is scored as 3; and complex thinking (as described for score level 3) *and* providing explanations is scored as 4.

**Expected Student Response.** Expected Student Responses was coded for technology activities from the methods class, and actual Student Response was coded based on samples of students’ work from the student teaching portfolios. This dimension determines how students show their work and/or explain their thinking about mathematical content.

Scores in this dimension are based on the IQA AR3 assignment rubric for Elaborateness of Students’ Responses, found or expected in the students’ written work. Expected Student responses or/and Student Response were scored within lesson activities as: simple response or fill in the blank (score 1), show mathematics procedures (score 2), show some type of representation or problem-solving process (score 3), and show some type of representation or problem-solving process and a written explanation (score 4).

To summarize, each lesson activity was scored on a scale of 0-4 using the rubrics for Potential of the Task (AR1; Appendix A), Description of Implementation / Implementation (AR2; Appendix B), and Expected Student Responses / Elaborateness of Student Responses (AR3; Appendix C). One set of scores for each PST was used to determine overall mean and median scores for Potential of the Task, Description of Implementation, and Expected Student Responses.
The technology activities from the pilot study were coded as described in this section, based on Potential of the Task, Described Implementation, and Expected Student Response. To establish reliability, a subset of tasks from the pilot study was double coded until two trained raters reached 80% exact-point agreement. Overall, 20% of instructional activities in the pilot study were consensus coded.

In this present study, all data were scored by the researcher, and then the research advisor scored randomly selected tasks (20% of the 68 activities from method course and 20% of the 14 activities from Showcase portfolio) to determine reliability. Overall exact scale-point agreement between the researcher and research advisor ranged from good (82%) to excellent (94%) for the individual rubrics. The agreement with research advisor was 94% for Potential of the Task, 82% for the Implementation and Described Implementation, and 88% for the Students Response and Expected Student Response. All coding questions were discussed between raters until reaching consensus. Upon achieving exact-point reliability higher than 80% for each rubric, the researcher coded the remaining technology activities individually. Overall exact scale-point agreement between the researcher and independent rater ranged from moderate (65%) to very good (88%) for the individual rubrics.

**Examples of coding of instructional activities.** Figures 8 through 12 illustrate one example on each scale, accompanied by explanations of how the IQA mathematics rubrics were used to score PSTs’ technology activities. Potential of the Task and Expected Student Response are discussed first; and examples of scoring Described Implementation are discussed later, to provide scenarios of how Described Implementation would be scored based on PSTs’ description of how they aim to use the specific technological tool in their lesson activity. All examples in the Figures are selected from the pilot study.
**Name the Fraction.** The “Name the Fraction” applet, http://nlvm.usu.edu/en/nav/frames_asid_104_g_2_t_1.html?from=category_g_2_t_1.html, in Figure 8 is identified as a Grade 3-4 activity. Students are only asked to “name the fraction shown by the shape”. *Potential of the Task* receives a score of 1, because students are only asked to provide the fraction notation (e.g., a memorized convention). The task directions do not require students to draw a diagram, perform a procedure, or explain the result. *Expected Student Response* also scores a 1, since students just enter the numbers in the box.

**Potential of the Task:** 1  
**Expected student response:** 1

*Figure 8.* Name the fraction activity. (NLVM website, n.d.-b).
Plotting Points. The “Plotting Points”,
http://resources.oswego.org/games/BillyBug2/bug2.html, example in Figure 9 is a game activity in which students control a bug on a coordinate plane that starts at (0,0). The aim of this activity is that students try to find given specified coordinates from all four coordinate with using left, right, below, and above arrows. The Potential of the Task receives a score of 2, because students are asked to identify given points on a coordinate grid (e.g., “procedures without connection”). The Expected Student Response is 1, because students are only asked to find given points by clicking the arrows on the x-y coordinates, and there is no indication in their response (“grabbing the location”) of the procedure they might have used to find the point or if they are relying on memorized knowledge.

**Figure 9.** Plotting points activity. (Oswego, n.d.)
Nets of 3-D shapes. The activity, [http://illuminations.nctm.org/Activity.aspx?id=3521](http://illuminations.nctm.org/Activity.aspx?id=3521), in Figure 10 requires students to explore shapes such as cubes, tetrahedron, or dodecahedron and how their solid forms from a 2-D net. Students are exploring multiple faces, edges, and vertices of the given shape to understand its 3D form. The task directions ask students: “For any polyhedron, what is the relationship between the number of faces, vertices, and edges?” The task provides complex thinking opportunities for students, but does not require an explanation; hence the score for Potential of the Task is 3. The Expected Student Response is score of 3, because student are required to find relationship between faces, edges, and vertices (corners) of each shape. Students must look for patterns and relationships, and they are doing more than applying a rote procedure or calculation, but they are not asked for an explanation or generalization for why the relationships occur. If the teacher would include directions that expect students to explain why the relationships occur and/or require students to explain the relationship between faces, edges and corner of each shape, the Expected Students Response would be 4. Conversely, if the directions or teacher’s expectations for this task just asked students to find “what is the number of faces, vertices, and edges of each shapes” instead of asking about the relationships between them, the score would be a 2.
Potential of the Task: 3

Expected Student Response: 3

Figure 10. Nets of 3-D shapes activity. (NCTM Illuminations, n.d.-b)

Quadratic Transformer. The aim of the Quadratic Transformer activity, http://seeingmath.concord.org/resources_files/QuadraticGeneral.html?, in Figure 11 is to help students to make sense of mathematical ideas of the graph and equation for a parabola and make connections between graphic and symbolic representation and how they relate to each other. The task directions ask, “How does the number you chose for the coefficient of x² (the letter a) change the shape of a parabola? Write your conclusions and explain your reasoning”. This activity requires explanation of what effect changing $a$ in $f(x)=ax^2$ and the values of $b$ and $c$ with the location of the vertex. Both Potential of the Task and Expected Student Response are scored a 4, because the task asks students to provide an explanation of their reasoning and understanding.
If the teachers’ expectation for students’ response would require students to “use the Quadratic Transformer to help you write the function rule for each of the parabolas in the web”, and did not require an explanation, the score of expected student response would be 3.

**Figure 11.** Quadratic transformer activity. (Seeingmath, n.d.)

**Examples for Described Implementation.** Explanations of these examples only include Potential of the Task and Expected Student Response. For a given task or technology applet, Described Implementation scores can be different based on how PSTs describe the implementation of the task or technology within the instructional activity. For Example,
Potential of Task and Expected Student Response scores are 1 for the Naming Fractions applet in Figure 8. However, Described Implementation scores could range from 1 to 4 depending on how the applet was incorporated into the lesson activity described by the PST. Described Implementation could be a score of 3 if the lesson activity required students to draw a visual model similar to the given shape to show an equivalent fraction. If students were also required to provide an explanation of why the two shapes show equivalent fractions, the Described Implementation score would be 4.

Example of a technology activity and samples of student work from PST’s student teaching classroom. Figure 12 demonstrates samples of a set of activities and students’ work. The aim of this activity is to help students to discover the Triangle Angle Sum Theorem. To investigate this activity students can click and drag the vertices of the triangle and use the sliders to rotate the vertices. The task is a set of problems, and includes six questions or problems. As mentioned in Chapter 2, a “mathematical task” is defined as a set of problems or a single complex problem that focuses students’ attention on a particular mathematical idea (Stein, Smith, Henningsen, & Silver, 2009), so this set of questions is considered as one task, and receives one score for each rubric: Potential of the Task, Implementation, and Students’ Responses.

The first two questions are about how to create three types of triangles. The third question asks student to record “the interior angle measures of the triangle for each case.” The fourth question requires writing an equation relating to the three types of triangles. Questions that have the highest cognitive demands (fifth and sixth questions) are, “What do you observe about the triangle’s three interior angles when the sliders are set to 180? Does the Triangle Angle Sum Theorem hold true for each case? Be prepared to explain your answer.” These questions require
students to explain their reasoning and understanding, so Potential of the Task is score of 4.

(Retrieved from [http://tube.geogebra.org/student/m28392](http://tube.geogebra.org/student/m28392)).
Figure 12. Sample of activities and students works. (Geogebra, n.d.-a).  

12b and 12c demonstrate the student’s work. The student provided one-word answers and fills in blanks in Figure 12b (which would score a 1 for Student Response if other questions were not included). In Figure 12c, the student shows written work for solving the equation (which by itself would score 2 for Student Response). The fifth question is left blank, and though the sixth question requires students to explain his/her reasoning, the student just gives a one-sentence answer. S/he does not provide thinking to explain why the idea is valid for him/her, so the score for Student Response is a 3. As mentioned before a set of problems or activities will only have one score for each dimension, and the overall Potential of the Task score is a 4, and the score of Student Response is a 3. The score of Implementation is also 3, because students engage in complex thinking or reasoning, or create meaning for mathematical procedures, but no explanation is provided.
Note that each technology activity in the student teaching portfolio contained at least 4 samples of students’ work. A set of student work was scored by considering the level of implementation and student responses provided by the majority of students.

In summary, each lesson activity received three IQA scores. PSTs’ technology activities from the methods class are scored for Potential of the Task, Described Implementation, and Expected Student Response. Technology activities and student work from PSTs’ student teaching classrooms were scored for Potential of the Task, Implementation, and Student Response. Scores are based on a scale of 0-4, where scores of 0-2 represent low-level demands and 3-4 indicate high-level demands across all of the rubrics.

3.5.2 Coding the LoTi Digital-Age Survey.

The LoTi survey was administered online to pre-service teachers through http://www.lotilounge.com/. The link was shared via email with participants after they had signed the consent form and provided an email address. A LoTi Digital-Age Survey Lounge account has been established for the Ahmet Akcay Dissertation Study. All participants needed the Group ID and Password to complete a one-time registration sequence that identifies them with the group and as an individual. All participants followed the instructions to access the LoTi Digital-Age Survey Lounge, take the questionnaire, and optionally print their individual results. A cover letter for the survey tool was attached.

Each PST received three scores from the LoTi Digital-Age Survey: Current Instructional Practice (CIP), Personal Computer Use (PCU), and Levels of Technology Implementation (LoTi) scores. The LoTi Digital-Age Survey uses a Likert scale ranging from 0 (N/A or Not
Applicable) to 7 (very true of me now). The questions for the CIP indicator include Questions 6, 20, 32, 41, and 50, and so the score ranges from zero to 35. Questions 13, 15, 18, 26, and 49 contribute to the PCU score, which ranges from zero to 35. The other remaining questions are marked for the LoTi score, which represents the eight levels of technology implementation (Appendix D) with each level receiving a score from zero to 35. After summing the scores, and then each scores will be divided for CIP, PCU, and LoTi levels to determine raw scores. These eight levels are:

- Level 0 - Non-use
- Level 1 - Awareness
- Level 2 - Exploration
- Level 3 - Infusion
- Level 4a - Integration: Mechanical
- Level 4b - Integration: Routine
- Level 5 - Expansion
- Level 6 - Refinement

Levels 0 to 3 are considered as teacher-centered instruction, and Level 4 to 6 characterize as student-centered learning from use of lower order thinking skills to use of higher order thinking with a level increase with LoTi. All raw scores can be summed, and divided by number of questions in each part to obtain averages for PCU, CIP, and each of the eight LoTi levels. Then, “the raw scores are then graphed to determine where each sample participant falls on a profile that ranges from “Not True of Me Now” to “Very True of Me Now” thus developing a profile for each sample participant that resembles a bar graph”, and “Information obtained from the bar
graph is then used to find each participant’s LoTi total score using the LoTi Calculation Key” (Appendix G) (Lemoine, 2007, 52 as cited in F. Saunders, personal communication, October 13, 2006). A LoTi score ranges from 0 to 6 (Appendix D). The data was exported from the LoTi Digital-Age Survey database to a Microsoft Excel spreadsheet then Statistical Package for the Social Sciences (SPSS) software to analyze.

3.6 Analysis

Quantitative research techniques were used for the methodology in this investigation. Ravid (2000) described quantitative research as explaining the relationships of cause and effect. In this section, analysis procedures will be explained for each research question.

Research Question One:

In order to answer Research Question One, descriptive statistics was used to show scores for Potential of the Task, Described Implementation, and Expected Students Response in the technology activities created or selected by PSTs. Specifically, the following sub-questions will be investigated under RQ1.

- What is the level of cognitive demand of the technology tasks created or selected by PSTs in technology activities for: 1) an assignment in a mathematics methods course, and 2) during student teaching?
- What is the level of cognitive demand of the implementation of the technology tasks as described in the lesson activities created by PSTs for: 1) an assignment in a mathematics methods course, and 2) during student teaching?
• What is the level of expected student responses in the technology activities created by PSTs for: 1) an assignment in a mathematics methods course, and 2) during student teaching?

• Are there differences between the level of cognitive demand of the instructional tasks, implementation of the instructional tasks as described, and of expected student responses in the technology activities created or selected by PSTs for an assignment in a mathematics methods course?

• Are there differences in the level of cognitive demand of the instructional tasks, implementation of the instructional tasks as described, and of expected student responses in the technology activities created or selected by PSTs for an assignment in a mathematics methods course by each grade level?

• Does the level of cognitive demand of the instructional tasks, implementation of the instructional tasks as described, and of expected student responses in the technology activities created or selected by secondary level PSTs for an assignment differ from the level of cognitive demand of the instructional tasks, implementation of the instructional tasks as described, and of expected student responses in the technology activities created or selected by secondary level PSTs for student teaching?

Means, medians, percentages and the frequency of technology activities at each IQA score level will be reported in a frequency table. This result allows for the comparison of Potential of the Task, Described Implementation, and Expected Students Response and to describe the level of cognitive demand of PSTs’ technology activities, as an indication of PSTs’ ability to plan lessons that incorporate technology in ways that supports students’ learning. Results of the present study are compared to previous research described in Chapter 2. Specific
examples of tasks, technology activities, and students’ work are shared and discussed under the Results and Discussion sections. Data was compiled in an Excel spreadsheet that was imported into the Statistical Package for Social Sciences, version 23 software application for final descriptive statistical analysis.

To make comparisons between rubrics (e.g., Potential of the Task vs. Described Implementation), means, medians, percentages and the frequency of technology activities at each IQA score level were used to determine if cognitive demands declined in students’ work or during implementation. These comparisons indicated whether PSTs are creating-describing instructional activities that take advantage of the high-level aspects of high-level tasks, or improving the demands of low-level tasks. Comparing the Potential of the Task and Described Implementation provided an indication of whether the cognitive demands of the task were maintained or decreased during implementation.

A one-way ANOVA was run to determine differences between grade levels for each IQA rubric. Non-parametric t-tests for paired values (Mann-Whitney U Test) was used to make comparisons between the technology activities designed by secondary level PSTs for method class and the technology activities used during student teaching. The technology activities PSTs designed for method classes were compared with the activities used during student teaching as an indication of whether ideas from the methods class would be evident in PSTs’ classroom practices during student teaching.

Research Question Two:
In order to answer Research Question Two, a one-way Analysis of Variance (ANOVA) test (for Grade Level Teaching), the range and distribution of LoTi Digital-Age scores (box plot), the means scores and standard deviation of the group of PSTs, and the percent of PSTs at each LoTi Digital-Age level was used to examine the result of LoTi Digital-Age Survey. The Statistical Package for Social Sciences (SPSS) 23.0 for OS X was used for the statistical analysis. There was only one independent variable, and Table 2 shows the independent variable used in the study. Current Instructional Practice (CIP), Personal Computer Use (PCU), Level of Technology Implementation (LoTi), and LoTi Digital-Age Survey total score are the dependent variable of this study. The data was exported from the LoTi Digital-Age Survey database to a Microsoft Excel spreadsheet for pre-analysis.

Research Question Three:

In order to determine how PSTs’ level of technology integration is related to the instructional quality (i.e., level of cognitive demand) of PSTs’ technology activities, correlational statistics were used. Bordens and Abbott (2008) described a correlational design as one that “determines whether two (or more) variables covary and, if so, to establish the directions, magnitudes, and forms of the observed relationships” (p.99). Test results were stated using the Pearson correlation method of analysis, and the significance level is determined as .05 for all statistical analyses.

3.7 Consent Procedures

An Institutional Review Board (IRB) expedited application was approved by the Duquesne University IRB. The proposed study met expedited status criteria, and the permission
to conduct this study was obtained on 05/06/2014 with Protocol # 2014-04-8. (Appendix K). The study was described to mathematics pre-service teachers in person, during a class session of their mathematics pedagogy course, by the doctoral candidate. During this class session, PSTs were asked to sign two copies of the consent form (Appendix K) and return one copy directly to the Graduate Researcher and retain the other copy for their records. The instructor was not in the classroom during the collection of Informed Consent Forms. The course instructor (research advisor and/or other mathematics education faculty) was not made aware of whom had chosen to participate until the end of the semester, after grades have been finalized.

Data collected from participants was de-identified by the doctoral candidate, using codes and pseudonyms, for the purpose of connecting the survey results and IQA scores. Names were disassociated with codes and all data was anonymous once the scores had been paired. All data collected from that participant was identified by the pseudonym. All information that linked pseudonyms and actual persons are kept in a locked file and only the researcher (doctoral candidate) has access to it. Any information obtained from this research is kept confidential. Data and results are not shared or made public in a way that indicates the identity of individual participants. Data about individual participants is not shared with the participants’ colleagues or administrators. It is possible that information gathered in research may become part of a published product. In written descriptions and in reports of what is learned from the study, the researchers will remove all information that identifies individuals.

No identifying information pertaining to students in the PSTs’ classrooms was collected. All K-12 student works are "blinded" such that researchers have no access to identifying information about K-12 students. K-12 students are not considered as subjects in this study.
Participants could withdraw from the study or discontinue their participation in the study at any time. If a pre-service teacher had elected to withdraw from the study, no data collected from that person would be analyzed as part of the study. (Note that no PSTs elected to withdraw from the study.) This study presented minimal risk to participants, no greater than encountered in everyday life. There are no direct benefits to participants, and pre-service teachers did not receive a stipend for participation in the study. There was no cost to pre-service teacher for participating in this study.

3.8 Study Design and Procedures

In this present study, the researcher evaluated the technological tools pre-service teachers (PST) were using and the mathematical quality of the instructional activities PSTs find or create during their methods classes and/or used during their student teaching. PSTs were asked to complete the LoTi survey regarding the implementation and availability of technology (personal and classroom). Participants were also asked to provide artifacts (i.e., copies of instructional tasks, samples of students’ work) from instructional activities using technology to teach mathematics that they: 1) created or found for their mathematics pedagogy course assignment; and 2) used to teach mathematics during student teaching. The study and data collection requirements were explained to PSTs by the researcher during the mathematics method courses.

The survey, instructional task and students’ work provided data to answer the research questions posed above. The IQA provides three scores that were analyzed to answer research question one; the LoTi Digital-Age Survey yields scores that were analyzed to answer research question two; and correlations between the LoTi Digital-Age Survey and IQA scores were analyzed to answer research question three.
3.8.1 Data Collection.

The participants of this study were pre-service mathematics teachers from a mid-size private university located in northeast US. The researcher described the study to mathematics pre-service teachers in person, during class sessions of PK-4 Numeracy Pedagogy, Teaching Mathematics Grades 4-8, Teaching Secondary Mathematics in Fall 2014 and Spring 2015. These courses are typically taught by the research advisor or mathematics education faculty at the University. After grades have been finalized for the semester, the researcher was provided the participants’ names, and assignments from those students were copied by the researcher. Sixty-six PSTs agreed to share their lesson activities and complete the survey.

Sixty-six PSTs who signed the consent form received an email about the study and a survey link via their initial email address in April 2015. Two weeks after the initial email had been sent, a follow-up email was sent to PSTs to remind them to complete survey. After the survey was conducted twice, the response rate remained low, so a third email contact was made in an attempt to improve the numbers of participants. The last survey deployment date was sent to PSTs in May 2015 via email. At the end of the survey deployment, only 20 LoTi-Digital Age Surveys had been completed by PSTs, giving a 30.30% response rate among participants. This low response rate is one of the study’s limitations. Technology activities were collected from elementary, middle, and secondary level of PSTs; however, Student Showcase portfolio was collected only from secondary level PSTs. Note that “n” in the “lesson plans and Student Portfolio columns” describes number of technology activities created by PSTs for method courses and student teaching, and “n” in “survey column” represents number of PSTs who completed the survey from each program.
Table 3

Descriptive Stats for Data Collection

<table>
<thead>
<tr>
<th>Program</th>
<th>Semester</th>
<th>Lesson Plans (n)</th>
<th>Student Portfolio (n)</th>
<th>Survey (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary</td>
<td>Fall 2014</td>
<td>31</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Spring 2015</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>Fall 2014</td>
<td>19</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Spring 2015</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary</td>
<td>Fall 2014</td>
<td>0</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Spring 2015</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The next chapter presents the results of the analyses.
CHAPTER IV
RESULTS

4.1 Introduction

Chapter 4 presents the level of technology integration of pre-service teachers (PST), the results of how PSTs planned to integrate technology into instructional activities, and how PSTs’ level of technology integration relates to the level of cognitive demands of the mathematics tasks in their mathematics technology activities. In this study, 68 instructional activities, 14 Showcase Portfolios, and 20 online survey responses were collected and analyzed. Data was analyzed using the Statistical Package for the Social Sciences (SPSS) version 23.0 for IOS.

The results of the study are organized according to the order of research questions. This section begins with a presentation of results on the cognitive demands of PSTs’ technology activities (RQ1), followed by results of the LoTi survey (RQ2), and concludes with results from the analyses of the relationship between cognitive demand and LoTi results (RQ3).

4.2 Research Question 1: The Level of Cognitive Demand of Pre-Service Teachers’ Technology Activities

To examine the technology activities selected or created by pre-service teachers (PST), the researcher posed the following research question:

- What are the cognitive demands of instructional activities when pre-service mathematics teachers are asked to integrate technology into mathematics lesson activities a) created for an assignment during the mathematics methods course; and b) created and used during student teaching?
To address the cognitive demand of each technology activity, the researcher used the Instructional Quality Assessment (IQA) (Boston, 2012) based on three indicators: a) instructional task as written or seen on website, b) description of how the task would be implemented or was implemented during the technology activity, and c) the level of response expected from or produced by students. The technology activities created for assignments in the methods course receive scores for: Potential of the Task, Described Implementation, and Expected Student Response. The technology activities created and used during student teaching receive scores for: Potential of the Task, Task Implementation, and Student Response. Scores of 0-2 indicate “low-level” cognitive demands (e.g., memorization, rote procedures or “procedures without connections”) and scores of 3-4 represent “high-level” cognitive demands (e.g., “procedures with connections” to meaning and sense-making, and “doing mathematics” or problem-solving).

Descriptive statistics provided in this section include means (on the scale of 0-4), medians, and the frequency and percentages of technology activities at each score level. Specific examples of tasks and instructional activities from PSTs’ “Technology Assignments” and “Showcase portfolio” are shared in Chapter 5. Results for the technology activities selected or created by PSTs for the methods courses in teaching elementary, middle, and secondary level mathematics are discussed below, organized by course.

4.2.1. Content Knowledge for Teaching Numeracy.

Forty-one (41) students in Numeracy Pedagogy PK-4 courses during Fall 2014 and Spring 2015 semesters agreed to participate in this study. Table 4 displays a summary of the specific technology resources PSTs selected for the elementary level technology activities. Note that all tasks are only counted once in this table, even when two forms of technology were used.
For example, using the NVLM website on the SmartBoard for a demonstration was reported as an Internet resource because NVLM is the primary technology resource in the technology activity.

Table 4

*Types of Technology Tools used in PSTs’ Technology Assignments in PK-4.*

<table>
<thead>
<tr>
<th>Types of Technology</th>
<th>Technology Activities (41)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internet sources</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>National Council of Teachers of Math</td>
<td>23</td>
</tr>
<tr>
<td>(NCTM) Illuminations</td>
<td></td>
</tr>
<tr>
<td>The National Library of Virtual</td>
<td>9</td>
</tr>
<tr>
<td>Manipulatives (NLVM)</td>
<td></td>
</tr>
<tr>
<td>National Center for Educational</td>
<td>4</td>
</tr>
<tr>
<td>Statistics (NCES)</td>
<td></td>
</tr>
<tr>
<td>Free.ed.gov</td>
<td>1</td>
</tr>
<tr>
<td>Dataintheclassroom.org</td>
<td>1</td>
</tr>
<tr>
<td>Figurethis.org</td>
<td>1</td>
</tr>
<tr>
<td>mathforum</td>
<td>1</td>
</tr>
<tr>
<td>Mathplayground</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>41</strong></td>
</tr>
</tbody>
</table>

Table 4 clearly shows that PSTs frequently selected National Council of Teachers of Mathematics (NCTM) Illuminations (23/41, 56%), and rarely selected other resources such as Free.ed.gov (1/41), Dataintheclassroom (1/41), figurethis.org (1/41), mathforum (1/41), and mathplayground (1/41) websites. The National Library of Virtual Manipulatives (NLVM) was
selected nine times (22 %), and National Center for Educational Statistics (NCES) was selected four times (10 %) by elementary level PSTs to create technology activities. Figure 13 provides a screenshot of the most frequently selected Internet resources by elementary level PSTs. Figure 13a is an example of a screenshot of an NCTM activity and Figure 13c is an example of a screenshot of an NVLM activity. Both resources were used frequently throughout the PK-4 mathematics methods course.

4.2.1.1 Cognitive Demands. Table 5 provides the frequency of each score level of the IQA rubrics, means, and medians regarding PSTs’ technology activities for the Numeracy Pedagogy PK-4 methods courses.

Table 5

IQA Scores for Technology Activities by Rubric Dimension for Elementary Level Mathematics Methods Course

<table>
<thead>
<tr>
<th>IQA Rubric</th>
<th>Mean</th>
<th>Median</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential of the Task</td>
<td>3.15</td>
<td>3</td>
<td>0 (0%)</td>
<td>2 (5%)</td>
<td>31 (75.5%)</td>
<td>8 (19.5%)</td>
</tr>
<tr>
<td>Described Implementation</td>
<td>3.30</td>
<td>3</td>
<td>0 (0%)</td>
<td>2 (5%)</td>
<td>25 (61%)</td>
<td>14 (34%)</td>
</tr>
<tr>
<td>Expected Student Responses</td>
<td>3.22</td>
<td>3</td>
<td>1 (2.5%)</td>
<td>3 (7.5%)</td>
<td>23 (56%)</td>
<td>14 (34%)</td>
</tr>
</tbody>
</table>

Of the 41 technology activities analyzed for elementary level methods courses: 1) only two (5%) had low-level cognitive demands for Potential of the Task; 2) only two (5%) had low-level cognitive demands for Described Implementation; and 3) only four (10%) had low-level demands for Expected Student Responses. The mean scores for each rubric are greater than 3,
and all medians are at score level 3. These data indicate that the technology activities selected or created by PSTs consistently have the potential to engage students in cognitively demanding mathematical thinking and reasoning. Scores of 4 indicate that 19.5% of tasks, 34% of instructional activities (described implementation), and 34% of expected student responses required students to explain their mathematical thinking and reasoning. Figure 13 shows examples of a screenshot of an NCTM and NLVM activity from the data collection from elementary PSTs. Figure 13b represents example of a low-level task, and 13d represents an example of a high-level task.
13a.


13b.

**Low–level task:**

“How many more students liked apple juice than orange juice?” This task is limited to engaging students in using a procedure, and students are only required to use prior instruction, experience, or placement of the task. The task does not require students to make connections to the meaning or concept.

13c.


13d.

**High-level task:**

The task is “Make rectangles with a certain number of pentominoes. Students must use three pentominoes to make a 3x5 rectangle and four pentominoes to makes a 4x5 rectangle.”

The task has the potential to engage students in complex thinking, reasoning or in creating meaning for mathematical idea, concepts, procedures, and/or relationships.
Figure 13. A screenshot of an NCTM and NLVM activities and an example of a high and low-level activity from the data collection from elementary PSTs

4.2.2 Teaching middle level mathematics.

Seventeen (17) PSTs in a methods course entitled “Teaching Middle Level Mathematics” agreed to participate in this study. Throughout the Middle Level Mathematics course, pair/groups of PSTs plan a set of technology-based instructional activities. Each group submits a collection of three technology activities that must contain the use of the SmartBoard, graphing calculator, and an Internet resource in ways that support students’ learning of specific mathematical ideas. In this course, PSTs worked in six groups of 2-3 PSTs each. Note that one group submitted one additional technology activity, generating 19 technology activities for analysis in this study.

Table 6 displays a summary of the type of technology used for the technology activities in this course within each broader category. Note that some tasks are only counted once in this table, even when two forms of technology were used (e.g., using NVLM on the SmartBoard for a demonstration).
Table 6

*Types of Technology Tools used in PSTs’ Technology Assignments in Middle Level*

<table>
<thead>
<tr>
<th>Types of Technology</th>
<th>Technology Activities (n = 19)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SmartBoard</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PowerPoint</td>
</tr>
<tr>
<td></td>
<td>Smart Exchange website</td>
</tr>
<tr>
<td></td>
<td>Modern Chalkboard</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Internet Resources</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The National Library of Virtual Manipulatives (NLVM)</td>
</tr>
<tr>
<td></td>
<td>Mathplayground</td>
</tr>
<tr>
<td></td>
<td>Shodor.org</td>
</tr>
<tr>
<td></td>
<td>Sheppard Software Website</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Graphing Calculator</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Texas Instruments Website</td>
</tr>
<tr>
<td></td>
<td>Mathbits</td>
</tr>
<tr>
<td></td>
<td>Math Buffalo State</td>
</tr>
<tr>
<td></td>
<td>Only graphing calculator</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
</tr>
</tbody>
</table>

The data in the Table 6 demonstrate that seven lesson activities involve the use of the SmartBoard, six use Internet resources, and six use the Graphing Calculator. 

*SmartBoard (Interactive White Board).* Four technology activities included only the SmartBoard with no additional tools or resources. PSTs used the SmartBoard to present the lesson through slides they had created. Two lesson activities included the Smart Exchange website and one activity used the Modern Chalkboard website to be displayed on the SmartBoard to do the instructional activities.
Internet Resources. Three PSTs used the Mathplayground website as an Internet resource. Each of The National Library of Virtual Manipulatives (NLVM) website, Shodor website, and Sheppard Software website was used by middle level PSTs only once.

Graphing Calculator. Two of the instructional activities were created only by using graphing calculator itself with no additional tools or resources. Two PSTs selected the Mathbits website as the basis of their instructional activities. The Texas Instruments (TI) website and Math Buffalo State website were each selected once. Figure 14 provides a screenshot of an activity from the data collection for SmartBoard (Figure 14a), graphing calculator (Figure 14b), and Internet sources (Figure 14c).
14b. Graphing Calculator activity

Writing Equation of Line

Write the equation of the line passing through the points A(2,-5) and B(4,1).

Solution:

Normal Solution: Of course you can simply use your calculator to help you find the slope (using the slope formula) and substitute your values into the point-slope form for the equation of a straight line.

Calculator Solution: The Statistics features of the graphing calculator can be used to write the equations of straight lines given points.

1. Enter the points into lists L1 and L2.

(See Basic Commands for entering data.)

Be careful to keep the x and corresponding y coordinates lined up horizontally.

2. Choose STAT. Arrow to the right to CALC at the top of the screen. Choose #4:LinReg(ax+b).

3. On the home screen you will need to tell the calculator which lists contain your points. If you also wish to quickly

14c. Internet source activity.

Figure 14. A screenshot of an activity from the data collection for SmartBoard, graphing calculator, and Internet.

4.2.2.1 Cognitive Demands. Table 7 provides the frequency of each score level of the IQA rubrics, means, and medians regarding PSTs’ technology activities for “Teaching Middle Level Mathematics” method courses.
Table 7

*IQA Scores for Technology Activities by Rubric Dimension for Middle Level Mathematics*

*Methods Course*

<table>
<thead>
<tr>
<th>IQA Rubric</th>
<th>Mean</th>
<th>Median</th>
<th>1 (0%)</th>
<th>2 (63.1%)</th>
<th>3 (15.8%)</th>
<th>4 (21.1%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential of the Task</td>
<td>2.58</td>
<td>2</td>
<td>0</td>
<td>12</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Described Implementation</td>
<td>2.74</td>
<td>3</td>
<td>0</td>
<td>9</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Expected Student Responses</td>
<td>2.63</td>
<td>3</td>
<td>3 (15.8%)</td>
<td>6 (31.6%)</td>
<td>5 (26.3%)</td>
<td>5 (26.3%)</td>
</tr>
</tbody>
</table>

A majority of tasks (12 out of 19; 63.1%) had low-level cognitive demands; although there are fairly even numbers of high-level and low level scores for Described Implementation of the technology activities (10 out of 19; 52.6%) and expected student responses (10 out of 19; 52.6%). Interestingly, three technology activities with Potential of the Task rated as low-level resulted in high-level cognitive demands for Described Implementation and Expected Student Response. The mean scores for each rubric are greater than 2.5, indicating that the technology activities would engage students in cognitively challenging mathematical work and thinking about half of the time.
<table>
<thead>
<tr>
<th>TASK</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low-Level Task</strong></td>
<td>Students are given a fraction in symbolic form (i.e. 1/5) and they have to match it to a visual representation of the fraction. The cognitive demand of this task is low-level, because students are only required to find equivalent to 1/5. The potential of the task is limited to engaging students in using a procedure.</td>
</tr>
<tr>
<td>What is equivalent to 1/5?</td>
<td></td>
</tr>
</tbody>
</table>

Eight PSTs in the “Teaching Secondary Mathematics Course participated, and 8 technology activities were analyzed. Table 8 displays a summary of the type of technology used for the technology activities in this course within each broader category.
Table 8

*Types of Technology Tools used in PSTs’ Technology Assignments in Secondary Level*

<table>
<thead>
<tr>
<th>Types of Technology</th>
<th>Technology Activities (n = 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internet resources</td>
<td>8</td>
</tr>
<tr>
<td>The National Library of Virtual Manipulatives (NLVM)</td>
<td>1</td>
</tr>
<tr>
<td>Geogebra (tube.geogebra)</td>
<td>4</td>
</tr>
<tr>
<td>Desmos</td>
<td>1</td>
</tr>
<tr>
<td>NCTM Illumination</td>
<td>1</td>
</tr>
<tr>
<td>Touchmathematics</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>8</strong></td>
</tr>
</tbody>
</table>

Table 8 shows that secondary level PSTs created instructional activities through using Internet resources. Four PSTs selected the Geogebra website, and other Internet resources were selected only once. In Figure 16, a screenshot of a GeoGebra activity from the data collection is provided.
This task can be used to help students understand the properties of z-scores and rules with the normal curve. PST would use this to help illustrate visual principals of the curve to reinforce conceptual ideas that may be hard to grasp.

Figure 16. A screenshot of a GeoGebra activity from the data collection. (GeoGebra, n.d.-b).

4.2.3.1 Cognitive Demands. Table 9 provides the frequency of each score level of the IQA rubrics, means, and medians regarding PSTs’ technology activities.

Table 9

IQA Scores for Technology Activities by Rubric Dimension for Secondary Level Mathematics Methods Course

<table>
<thead>
<tr>
<th>IQA Rubric</th>
<th>Number (% at each Score Level</th>
<th>Mean</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential of the Task</td>
<td></td>
<td>2.75</td>
<td>3</td>
</tr>
<tr>
<td>Described Implementation</td>
<td></td>
<td>3.38</td>
<td>3</td>
</tr>
<tr>
<td>Expected Student Responses</td>
<td></td>
<td>3.38</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (0%)</td>
<td>2 (25%)</td>
<td>6 (75%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>5 (62.5%)</td>
<td>3 (37.5%)</td>
</tr>
<tr>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>5 (62.5%)</td>
<td>3 (37.5%)</td>
</tr>
</tbody>
</table>

Retrieved from http://tube.geogebra.org/student/b77111#material/20613
The majority of technology activities had high-level cognitive demands (6 of 8; 75%) and two (25%) had low-level cognitive demands, although all Described Implementation and Expected Student Responses in the technology activities were rated as high-level cognitive demands. Two technology activities with low-level cognitive demands tasks resulted in high-level cognitive demands for Described Implementation and Expected Student Response. Figure 17 demonstrates an example of a high- and low-cognitive demand activity from the data collection from secondary PSTs.
<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low-level task:</strong></td>
<td>The activity allows students to plot points and make equations. Students can manipulate variables to see how the variables affect the graphs of different equations. Students are asked to find the equation that fit along five points. They could use the pre-created graph to manipulate the variables until they line up with the points. It is a low-level task, because the task does not require students to make connections to the meaning or concept.</td>
</tr>
</tbody>
</table>

High-level task:

It is a National Library of Virtual Manipulatives activity. This manipulative is designed to teach students how to solve linear equations by showing how to balance equations. It is a very literal interpretation as it shows a scale and the student must work to keep both sides balanced. The task is “to balance beam pants to represent the equation”. This is a high-level task, because students are required to engage in complex thinking or in creating meaning for mathematical concepts, procedures, and/or relationships.


Figure 17. An example of a high and low activity from secondary PSTs.
4.2.4 Overall results for cognitive demands.

Table 10 provides the cognitive demands of the 68 technology activities overall, from elementary (41), middle level (19), and secondary mathematics (8) PSTs.

Table 10

**IQA Scores for Technology Activities by Rubric Dimension for All Level Mathematics Methods**

<table>
<thead>
<tr>
<th>Course</th>
<th>Number (%) at each Score Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>IQA Rubric</strong></td>
<td><strong>Mean</strong></td>
</tr>
<tr>
<td>Potential of the Task</td>
<td>3.00</td>
</tr>
<tr>
<td>Described Implementation</td>
<td>3.18</td>
</tr>
<tr>
<td>Expected Student Responses</td>
<td>3.10</td>
</tr>
<tr>
<td>Responses</td>
<td></td>
</tr>
</tbody>
</table>

Overall results indicated that PSTs overwhelmingly selected or created technology-based instructional tasks with high-level cognitive demands (52/68; 76%), planned instructional activities to engage students in cognitively challenging mathematical work and thinking (57/68; 83.8%), and expected high-level student-responses and products (55/68; 80.9%). Five technology activities that began with low-level mathematics tasks resulted in high-level cognitive demands for Described Implementation. Three technology activities that began with low-level mathematics tasks resulted in high-level cognitive demands for Expected Student Response. Scores of 4 indicate that 22% of tasks, 33.8% of instructional activities, and 35.3% of expected student responses required students to explain their mathematical thinking and reasoning. The
results suggest that a methods course focused on cognitively challenging tasks and task implementation may have supported PSTs to incorporate technology into instruction in ways that support students’ learning of mathematics.

A one-way analysis of variance (ANOVA) was the statistical tool to evaluate differences between grade levels for each of the IQA rubrics. The independent variable, grade level, included three levels: elementary (Pre-4), middle, and secondary. The dependent variable was the IQA rubrics: Potential of the Task, Described Implementation, and Expected Student Response. An ANOVA test compared the level of significance produced by the inferential procedure with an alpha level of 0.05. As shown in Table 11, a value of less than 0.05 in the significance column indicated that there was a statistically significant difference between independent variables.

The ANOVA was significant, $F(2, 65) = 6.695, p = .002$ for Potential of the Task, $F(2, 65) = 5.593, p = .006$ for Described Implementation, and $F(2, 65) = 4.013, p = .023$ for Expected Student Response. Follow-up tests were conducted to evaluate pairwise differences among the means. There was a significant difference between middle level and elementary level for Potential of the Task, Described Implementation, and Expected Student Response, with the middle level means significantly lower than the elementary level means for all IQA rubrics. There was a marginally significant difference between secondary and middle level for described implementation ($p = .051$). However, no significant difference was found between secondary level versus middle level for Potential of the Task and Expected Student Response or secondary level versus elementary level for all IQA rubrics.
Table 11

*The grade-level comparisons for each IQA Rubric*

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>(I) Grade</th>
<th>(J) Grade</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task</td>
<td>Elementary</td>
<td>Middle</td>
<td>.59178*</td>
<td>.16841</td>
<td>.002</td>
<td>.021878</td>
<td>.9957</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Secondary</td>
<td>.42073</td>
<td>.23455</td>
<td>.180</td>
<td>.1418</td>
<td>.9833</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>Secondary</td>
<td>-.17105</td>
<td>.25576</td>
<td>.782</td>
<td>.7845</td>
<td>.4424</td>
<td></td>
</tr>
<tr>
<td>Described</td>
<td>Elementary</td>
<td>Middle</td>
<td>.55584*</td>
<td>.17568</td>
<td>.007</td>
<td>.1345</td>
<td>.9772</td>
<td></td>
</tr>
<tr>
<td>Implementation</td>
<td>Secondary</td>
<td>-.08232</td>
<td>.24467</td>
<td>.940</td>
<td>.6692</td>
<td>.5045</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>Secondary</td>
<td>-.63816</td>
<td>.26680</td>
<td>.051</td>
<td>1.2781</td>
<td>.0018</td>
<td></td>
</tr>
<tr>
<td>Expected Student</td>
<td>Elementary</td>
<td>Middle</td>
<td>.56354*</td>
<td>.21970</td>
<td>.033</td>
<td>.0366</td>
<td>1.0905</td>
<td></td>
</tr>
<tr>
<td>Response</td>
<td>Secondary</td>
<td>-.17988</td>
<td>.30598</td>
<td>.827</td>
<td>.9138</td>
<td>.5540</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>Secondary</td>
<td>-.74342</td>
<td>.33365</td>
<td>.074</td>
<td>1.5437</td>
<td>.0568</td>
<td></td>
</tr>
</tbody>
</table>

* The mean difference is significant at the 0.05 level.

4.2.5 *Showcase portfolio.*

Technology activities selected or created by secondary level PSTs during student teaching and included in the Showcase Portfolio show PSTs’ ability to integrate technology into the teaching and learning of mathematics. Table 12 displays a summary of the specific technology resources PSTs selected for the Showcase Portfolio, within SmartBoard, Internet resources, and graphing calculator. Note that all technology activities are only counted once in Table 12 even when two forms of technology were used. For example, using the Texas Instrument (TI) website on the SmartBoard for a demonstration was reported as a graphing calculator activity, because TI is the primary technology resource. The category of SmartBoard
was not reported as a primary tool or resource, because many PSTs used the SmartBoard for demonstration when the Internet or graphing calculator was the primary resource.

Table 12

*Types of Technology Tools used in PSTs’ Technology Assignments for Student Portfolio*

<table>
<thead>
<tr>
<th>Types of Technology</th>
<th>Technology Activities (n = 14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internet Resources</td>
<td>8</td>
</tr>
<tr>
<td>National Council of Teachers of Mathematics (NCTM) Illuminations</td>
<td>3</td>
</tr>
<tr>
<td>Geogebra</td>
<td>3</td>
</tr>
<tr>
<td>Pearson Education</td>
<td>1</td>
</tr>
<tr>
<td>Youtube</td>
<td>1</td>
</tr>
<tr>
<td>Graphing Calculator</td>
<td>6</td>
</tr>
<tr>
<td>Only graphing calculator</td>
<td>4</td>
</tr>
<tr>
<td>Texas Instrument (TI) website</td>
<td>2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>14</td>
</tr>
</tbody>
</table>

*Internet Resources.* Eight (57%) activities included Internet resources (website) selected by PSTs for technology activities in the Showcase Portfolios. National Council of Teachers of Mathematics (NCTM) Illuminations and Geogebra were selected three times (21%).

*Graphing Calculator.* Six (43%) activities included graphing calculators. Four instructional activities (29%) utilized the graphing calculator without additional resources and two activities used Texas Instrument (TI) website. For example, one activity in the data collection describes how to graph a piece-wise function using the graphing calculator. Directions for using the graphing calculator are provided in Figure 14b.
**4.2.5.1 Cognitive Demands.** Table 13 provides the frequency of each score level of the IQA rubrics, means, and medians regarding the technology activities in PSTs’ showcase portfolios.

Table 13

_IQA Scores for Student Showcase by Rubric Dimension._

<table>
<thead>
<tr>
<th>IQA Rubric</th>
<th>Mean</th>
<th>Median</th>
<th>Number (%) at each Score Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 (0%)</td>
</tr>
<tr>
<td>Potential of the Task</td>
<td>3.36</td>
<td>3</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Implementation</td>
<td>3.00</td>
<td>3</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Student Responses</td>
<td>2.86</td>
<td>3</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

The majority of Potential of the Tasks (13/14; 93%), Implementation (11/14; 78.6%), and Student Response (10/14; 71.4%) had high-level cognitive demands. However, some technology activities contained high-level tasks that declined in cognitive demand during Implementation and Student Response.

Non-parametric t-tests for paired values (Mann-Whitney U Test) was conducted to evaluate differences between technology activities created by secondary level PSTs and Showcase Portfolios created by secondary level PSTs. The independent variable was technology activities and Showcase Portfolios, and the dependent variable was the IQA rubrics: Potential of the Task, Implementation/Described Implementation, and Student Response/Expected Student Response. A non-parametric t-tests for paired values (Mann-Whitney U Test) compared the level of significance produced by the inferential procedure with an alpha level of 0.05. As shown in
Table 14, a value of less than 0.05 in the significance (2-tailed) column indicated that there was a statistically significant difference between independent variables for only Potential of the Task.

Table 14

*The Comparisons of Technology Activities Created by Secondary Level PSTs versus Showcase Portfolio (Mann-Whitney Test)*

<table>
<thead>
<tr>
<th>Test Statisticsa</th>
<th>Task</th>
<th>Described Implementation</th>
<th>Student Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mann-Whitney U</td>
<td>28.000</td>
<td>39.500</td>
<td>33.000</td>
</tr>
<tr>
<td>Wilcoxon W</td>
<td>64.000</td>
<td>144.500</td>
<td>138.000</td>
</tr>
<tr>
<td>Z</td>
<td>-2.174</td>
<td>-1.281</td>
<td>-1.780</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.030</td>
<td>.200</td>
<td>.075</td>
</tr>
<tr>
<td>Exact Sig. [2*(1-tailed Sig.)]</td>
<td>.059b</td>
<td>.267b</td>
<td>.127b</td>
</tr>
</tbody>
</table>

a. Grouping Variable: Grade Level

A Mann-Whitney U test was conducted to evaluate the differences between technology activities created by secondary level PSTs versus showcase portfolio. The mean score of technology activities was lower than the mean score of Showcase portfolio for the Task. The results of the test were in the expected direction and significant for Task, $z = -2.174$, $p < .05$. Technology activities had an average rank of 13.50, whereas Showcase portfolio had an average rank of 8.00. However, the test was not significant, $z = -1.281$, $p = .20$, for Implementation/Described Implementation, and $z = -1.780$, $p = .075$, for Student Response/Expected Student Response. (Note that Appendix N shows independent t-test result for the comparisons of technology activities created by secondary level PSTs versus showcase portfolio).
This investigation found that in technology activities, PSTs could plan instructional activities with high cognitive demands (Table 10). PSTs supplemented the original task directions in 5 of 16 (31.25%) low-demand technology tasks to result in high cognitive demands for Described Implementation and 3 of 16 (18.75%) tasks for Expected Student Response. Also, 8 (11.80%) tasks that began lower than a 4 for Potential of the Task resulted score of a 4 for Described Implementation, and 9 (13.2%) tasks that began lower than a 4 resulted in a score of 4 for Expected Student Response, indicating that PSTs designed activities which required students to provide explanations of their mathematical thinking and reasoning. However for Showcase Portfolios (Table 13), secondary level PSTs could plan instructional activities with high cognitive demands, but 2 (14.3%) high-level tasks resulted in low-level cognitive demands for Implementation, and 3 (21.4%) high-level tasks resulted in low-level cognitive demands for Student Response. Also, 3 of 6 (50%) tasks that began at a score of 4 for Potential of the Task resulted in lower scores for Implementation, and 4 of 6 (66.7%) tasks at a score of 4 for resulted in a lower score for Student Response, indicating that students did not provide explanations of their mathematical thinking and reasoning even though it was required by the task.

It is interesting that PSTs selected or created high-level technology tasks during student teaching, when they were able to actually use them in the teaching and learning environment with students. Research in mathematics education suggests that the level of cognitive demands often declines during the teaching episode (e.g., Kessler, Stein & Schunn, 2015; Stein, Grover, & Henningsen, 1996; Stein & Henningsen, 1997). However, for the technology activities in PSTs student teaching Showcase Portfolios, samples of students’ work indicated that PSTs mostly maintained or increased level of cognitive demands of the tasks during implementation and in students’ responses.
4.3 Research Question 2: Level of Technology Innovation (LoTi) Digital Age Survey

The second question of this study is, “What is the mathematics pre-service teachers’ level of technology integration?” The second research question determined the PST’s level of technology integration using the results of the online LoTi Digital-Age survey analyzed by the LoTi profile. The LoTi survey instrument measures three primary components: Current Instructional Practice (CIP), Personal Computer Use (PCU), and Levels of Technology Implementation (LoTi). These three indicators are essential to identify technology integration into classroom instruction. A total of 20 PSTs completed the LoTi Digital Age survey. The CIP, PCU, and LoTi scores for PSTs were determined. The data was obtained from the LoTi Profiler website. The LoTi Profiler website “generate reports” menu is available in the LoTi Lounge account, and it was designed to easily create customized LoTi Technology Use Profiles of a group's data across three components. CIP, PCU, and LoTi data are automatically load in graph format. The descriptive statistics of CIP, PCU, LoTi scores for PSTs can be found in Table 15.

Table 15

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Min</th>
<th>Max</th>
<th>M</th>
<th>S.D</th>
</tr>
</thead>
<tbody>
<tr>
<td>LoTi</td>
<td>20</td>
<td>2</td>
<td>5</td>
<td>3.40</td>
<td>.940</td>
</tr>
<tr>
<td>PCU</td>
<td>20</td>
<td>2</td>
<td>7</td>
<td>4.35</td>
<td>1.387</td>
</tr>
<tr>
<td>CIP</td>
<td>20</td>
<td>3</td>
<td>7</td>
<td>5.30</td>
<td>1.129</td>
</tr>
</tbody>
</table>

The Current Instructional Practices (CIP) Profile reveals each participant's support for or implementation of instructional practices consistent with a learner-based curriculum design and research-based best practices. The CIP intensity levels are from 0 to 7, with 0 representing no
classroom setting and 7 representing the alignment of instructional practices with a learner-based approach. Levels 0-4 focus on “teacher-directed instruction of subject-based material”, and levels 5-7 are “indicative of a more learner-centered instructional approach and student-driven questions and problems” (Berkely-Jones, 2012; p. 62). Figure 18 displays CIP intensity levels of the participants. The CIP intensity level of the group was level 5, described as:

At a CIP Intensity Level 5, the participant's instructional practices tend to lean more toward a student-directed approach. The essential content embedded in the standards emerges based on students "need to know" as they attempt to research and solve issues of importance to them using critical thinking and problem-solving skills. The types of learning activities and teaching strategies used in the learning environment are diversified and driven by student questions. Both students and teachers are involved in devising appropriate assessment instruments (e.g., performance-based, journals, peer reviews, self-reflections) by which student performance will be assessed. The use of limited horizontal and vertical differentiated strategies are present based on student interests, modality strengths, learning profile and/or readiness levels (Learning Quest, 2011).
No participant was found on the intensity level below 3. Only 25% participants were at intensity level 4 and below, and 75% participants were at level 5 and above. This indicates that most of the participants aim to implement more learner-centered instructional approach than teacher-centered approach in their instructional practices.

The Personal Computer Use (PCU) Profile addresses each participant's fluency level with digital tools and resources for student learning as well as their use in the workplace. The PCU also offers eight response options ranking from 0 to 7: 0 indicates no skill in the use of computers, and 7 representing high proficiency in the use of computers. Figure 19 displays the personal computer use (PCU). The PCU intensity level was 4, indicating:

PCU Intensity Level 4 indicates that the participant demonstrates moderate to high fluency with using digital tools and resources for student learning. Participants at Intensity Level 4 commonly use a broader range of digital-age media and formats in support of their curriculum and instructional strategies. Participants at this level model
the safe, legal, and ethical uses of digital information and technologies and participate in local discussion forums that advocate the positive impact of existing digital tools and resources on student success in the classroom (Learning Quest, 2011).

Figure 19. Personal computer use (PCU) ranking

No participant was found on the intensity level at 0 and 1, which indicates no participants had no computer skills. Most of the participants (75%) were on intensity level 3, 4, and 5. The Levels of Teaching Innovation (LoTi) Profile approximates the degree to which each participant is either supporting or implementing the tenets of digital-age teaching and learning in a classroom setting. The LoTi scale ranking is from 0 to 6. Level 0 indicates “Non-use and perceived lack of access or time” and level 6 indicates “Refinement”. Figure 20 displays the level of teaching innovation by participants. The LoTi level with the highest intensity was level 4a (Integration: Mechanical) described as:
At a Level 4a (Integration: Mechanical) students are engaged in exploring real-world issues and solving authentic problems using the available digital and/or environmental resources; however, the teacher may experience classroom management (e.g., disciplinary problems) or school climate issues (lack of support from colleagues) that restrict full-scale integration. Heavy reliance is placed on prepackaged materials and/or outside resources (e.g., assistance from other colleagues) that aid the teacher in sustaining engaged student-directed learning. Emphasis is placed on the constructivist, problem-based models of teaching that require higher levels of student cognitive processing (e.g., Bloom Levels - analyzing, evaluating, creating; Webb’s Levels - short-term strategic thinking, extended strategic thinking) and in-depth examination of the content (Learning Quest, 2011).

Figure 20. The level of teaching innovation (LoTi) ranking
The results revealed that 9 of the participants (45%) met the target technology level of LoTi 4b or higher, and 11 of them (55%) did not. Only 8 (40%) participants were at Level 4b: Integration (routine) and 1 (5%) at Level 5: Expansion.

Table 16 represents descriptive statistics of means and standard divisions of LoTi, PCU, and CIP for each grade level.

To identify differences between grade levels for LoTi-Digital Age levels, one-way ANOVA was conducted. Table 16 demonstrates the result of one-way ANOVA. The independent variable, grade level, included three levels: elementary (Pre-4), middle, and secondary. The dependent variable was the LoTi-Digital Age Indicators: LoTi, PCU, and CIP. An ANOVA test compared the level of significance produced by the inferential procedure with an alpha level of 0.05. As shown in Table 16, there is not a value of less than 0.05 in the
significance column, indicating that there was not a statistically significant difference between independent variables.

Table 17

*Grade level comparison for LoTi, PCU, and CIP*

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>LoTi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>4.092</td>
<td>2</td>
<td>2.046</td>
<td>2.737</td>
<td>.093</td>
</tr>
<tr>
<td>Within Groups</td>
<td>12.708</td>
<td>17</td>
<td>.748</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>16.800</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCU</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>3.008</td>
<td>2</td>
<td>1.504</td>
<td>.762</td>
<td>.482</td>
</tr>
<tr>
<td>Within Groups</td>
<td>33.542</td>
<td>17</td>
<td>1.973</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>36.550</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>.367</td>
<td>2</td>
<td>.183</td>
<td>.131</td>
<td>.878</td>
</tr>
<tr>
<td>Within Groups</td>
<td>23.833</td>
<td>17</td>
<td>1.402</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>24.200</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The ANOVA was not significant, F (2, 17) = 2.737, p > .05 for LoTi, F (2, 17) = .762, p > .05 for PCU, and F (2, 17) = .131, p > .05 for CIP. A follow-up test was not conducted to evaluate pairwise differences among the means, because no significance was found.

4.4 Research Question 3: Relationship between PSTs’ Level of Technology Integration and the Level of Cognitive Demand of Instructional Tasks

A Pearson Correlation was run to analyze and generate results for Research Question 3 to determine the relationship between PSTs’ level of technology integration and the level of cognitive demand of instructional tasks in PSTs’ technology activities. The following research questions was posted:
• How is PSTs’ level of technology integration related to the level of cognitive demand of instructional tasks, implementation, and expected student response in PSTs’ mathematics lesson activities that integrate technology?

After the level of cognitive demand of instructional tasks and PSTs’ level of technology implementation had been determined, a Pearson’s correlation coefficient test was conduct to determine the relationship between cognitive demand of technology activities (Task, Described Implementation, and Expected Student Response) and PSTs’ level of the technology implementation (three aspects: LoTi, CIP, and PCU).

The Pearson’s correlation coefficient for LoTi scores versus Task scores (r = .175, p > .05) showed no significance, as well as Described Implementation (r = .218, p > .05), and Expected Student Response (r = .210, p > .05). The implication shows weak correlation exists between cognitive demands of technology activities and PSTs’ level of technology implementation (LoTi).

The correlation coefficients between PCU and Task scores (r = -.15, p > .05), Described Implementation (r = .284, p > .05), and Expected Student Response (r = .147, p > .05) were not significant. The implication is that weak correlation exists between the level of cognitive demand of technology activities and PSTs’ personal computer use (PCU).

The correlation coefficients between CIP and Task scores (r = .037, p > .05), Described of Implementation (r = -.091, p > .05), and Expected Student Response (r = -.033, p > .05) were not significant. The implication is that weak correlation exists between the level of cognitive demand of technology activities and PSTs’ current instructional practices (CIP).
Table 18

Correlation between the LoTi subscales and cognitive demand of instructional tasks

<table>
<thead>
<tr>
<th></th>
<th>Correlations</th>
<th>Task</th>
<th>Described of Implementation</th>
<th>Expected Student Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>LoTi</td>
<td>Pearson Correlation</td>
<td>.175</td>
<td>.218</td>
<td>.210</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.460</td>
<td>.355</td>
<td>.374</td>
</tr>
<tr>
<td>PCU</td>
<td>Pearson Correlation</td>
<td>-.015</td>
<td>.284</td>
<td>.147</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.950</td>
<td>.226</td>
<td>.536</td>
</tr>
<tr>
<td>CIP</td>
<td>Pearson Correlation</td>
<td>.037</td>
<td>-.091</td>
<td>-.033</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.879</td>
<td>.703</td>
<td>.891</td>
</tr>
</tbody>
</table>

Table 18 shows the analysis of Pearson’s correlation coefficient. The coefficient values are negative for PCU versus Task and CIP versus Described Implementation and Expected Student Response, and these coefficient values show very weak relationships.

In addition to Pearson Correlation, chi-square tests were used to identify any associations between LoTi Digital-Age levels (high, low) and IQA rubrics (high, low). The results show that there is no statistically significant association between Potential of the Task and LoTi score, Described Implementation and LoTi score, and Expected Student Response and LoTi score. Also, it is clear that the strength of association between the variables is very weak. For SPSS results of the chi-squared tests, see Appendix O.

Briefly, there is a weak relationship between PSTs’ levels of technology integration and the level of cognitive demand of instructional tasks, implementation, or expected student response in PSTs’ mathematics lesson activities that integrate technology.
4.5 Summary

Chapter four presents a detailed description of the results of this study examining PSTs’ integration of technology and how the integration of technology influences the level of cognitive demands of mathematics technology activities created or selected by PSTs. Data were collected from PSTs in a mid-size private university using the LoTi Digital Age Survey, lesson activities and Showcase Portfolios (with samples of students’ work) that incorporate technology. Data were collected from 66 PSTs, resulting in 68 instructional activities, 14 Showcase Portfolios, and 20 survey responses with a 30.30% survey-response rate. Note that the study has a survey-response rate just above the acceptable minimum of 30%. The data were analyzed using the SPSS package and LoTi profiler software.

Results indicated that elementary level PSTs overwhelmingly selected or created high-level cognitive demands instructional tasks in their technology activities, and maintained the high-level demands in the Described Implementation of the technology activities. Twenty-two percent (22%) of tasks, 33.8% of instructional activities, and 35.3% of expected student responses were at a 4, requiring students to explain their mathematical thinking and reasoning. However, two technology activities with high-level tasks decreased in the Expected Student Response. Middle level PSTs selected or created more low-level instructional tasks than high-level, although they were fairly even with high and low-level Described Implementation and Expected Student Response. The majority of secondary-level PSTs selected high-level tasks, and all of tasks resulted in high-level Described Implementation and Expected Student Response. Almost all tasks in the Showcase Portfolios selected by PSTs were high-level, however (as indicated by students’ work) two high-level tasks decreased during Implementation and three decreased for Expected Student Response.
LoTi Digital-Age Survey determined PSTs’ levels of technology integration and knowledge. LoTi Digital-Age Survey has three indicators: level of technology implementation (LoTi), current instructional practices (CIP), and personal computer use (PCU) scores. The results showed a more learner-centered instructional approach and student-driven questions and problems, moderate to high fluency with using digital tools and resources for student learning, and moderate PSTs’ implementation of instructional technological tools in the classroom settings (LoTi). Results of the analyses on the relationship between PSTs’ level of technology implementation and level of cognitive demands of technology activities showed no correlation. Results of this study may contribute to the development of future technology professional development programs. A discussion of these results, examples of selected instructional activities, and recommendations for future research and practice appear in Chapter 5.
CHAPTER V
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Introduction

This chapter discusses the results of the analyses and presents case studies to illustrate the importance of these results in teaching mathematics with technology. Conclusions drawn from the analyses and the implications of the findings are discussed. Finally, recommendations for technology teacher education and professional development, limitations, and future research are discussed.

5.2 Summary of Findings

The purpose of this study was to determine pre-service teachers’ (PST) ability to integrate technological tools into instructional activities in mathematics in ways that support students’ high-level thinking and reasoning. The following research questions were investigated:

1) What are the cognitive demands of instructional tasks when pre-service mathematics teachers are asked to integrate technology into mathematics lesson activities: a) created for an assignment during the mathematics methods course; and b) created and used during student teaching?

2) What is the mathematics pre-service teachers’ level of technology integration?

3) How is PSTs’ level of technology integration (RQ2) related to the level of cognitive demand of instructional tasks in PSTs’ mathematics lesson activities that integrate technology (RQ1)?

Results for the research questions were presented in Chapter 4. In this Chapter, the researcher presents the implications of those findings, organized by research question.
5.2.1 Cognitive demand.

In this study, the researcher examined technology-based instructional activities created by secondary level PSTs for a course assignment or for their student teaching Showcase portfolios. All of the examples provided in this section are based on instructional activities collected as data in this study. General technologies such as Internet sources, graphing calculators, and the SmartBoard were selected by PSTs to support a variety of mathematical tasks. In addition, many PSTs created instructional activities that used the SmartBoard to display Internet-based activities.

The researcher hypothesizes that PSTs’ overall success in selecting and designing cognitively demanding technology-based instructional activities is due to a very strong focus on the cognitive demands of tasks and task implementation throughout each of the methods courses. In each course, PSTs complete a Task Sort activity (Smith et al., 2004), are provided with the Task Analysis Guide (Stein et al., 2009), and are required to select high-level tasks as the basis for the lesson plans they create. They analyze written and video cases of mathematics instruction and identify features of lessons that served to maintain or reduce the cognitive demands, and they are often asked to reflect on lessons from the field classroom using those same factors (e.g., Henningsen and Stein, 1997). This is important because it suggests that focusing on cognitive demands throughout a methods course may be a productive pathway for supporting PSTs to use technology in ways that enhance students’ mathematical learning.

In discussing the findings for the data sources (assignments and Showcase Portfolios) and levels of candidates (elementary, middle level, secondary) in this section, the researcher will also offer other possible hypotheses for the results.

5.2.1.1 Technology activities created for course assignments. Almost all elementary level PSTs selected or designed technology-based instructional activities with cognitively
demanding tasks (95%), implementation (95%), and expected student responses (90%).

Elementary level PSTs produced technology based instructional activities during the course and demonstrated the ability to plan effective mathematics instruction that integrates technology. Elementary level PSTs’ success at designing technology activities with high cognitive demands may have been due to the fact that the National Council of Teachers of Mathematics (NCTM) Illuminations site and the National Library of Virtual Manipulatives (NLVM) site had been used by the instructor and PSTs frequently during the method course in support of PSTs’ own learning of mathematics and as resources PSTs might use to support their students’ learning of mathematics (Classroom instructor, personal communication, October 15, 2015). NCTM and NVLM are popular web-based virtual manipulatives tools to support mathematical concepts thorough different representations. Because of the nature of these websites, PSTs easily selected or/and designed high-level technology-based mathematical tasks. Even so, the vast majority of elementary PSTs in the study still demonstrated the ability to: 1) design high-level instructional activities using the technology, or 2) identify high-level tasks and instructional activities provided by the websites. Since elementary teachers request their students use technology in the classroom more often than middle level teachers (Bebell, et al., 2004), this finding is important because the elementary PSTs in this study designed activities that would provide students in elementary schools opportunities to actively engage with mathematics using technology.

While the majority of middle level PSTs selected technology tasks with low-level cognitive demands (63.1%), the majority was then able to design technology-based instructional activities with cognitively descriptions of implementation (52.7%) and expected student response (52.7%). Interestingly, the mean score of Described Implementation and Expected Student Response were higher than the mean score of Potential of the Task, indicating that PSTs
designed instructional activities and expected students’ responses that increased the demands of the tasks and supported students’ engagement in the tasks at a high-level. In many large-scale studies of mathematics teachers’ use of tasks during instruction, tasks typically have higher cognitive demands than implementation and discussion (Boston & Wilhelm, 2015). In other words, teachers do not often plan to implement or actually implement instructional activities with higher demands than the tasks themselves.

Middle level PSTs may have had more difficulty selecting high-demand tasks than elementary or secondary PSTs because of the context of the technology assignment given in the middle level methods course. While the directions were the same as those given to elementary and secondary PSTs (see Appendix M). They had to choose technology tasks that promoted students’ learning of specific mathematical ideas aligned to a unit of instruction they were planning in the course. For this reason, middle level PSTs may have searched for technology tasks based on mathematical topics (rather than level of cognitive demand) and then adapted those tasks or created instructional activities with higher-level demands.

Secondary level PSTs selected technology resources and designed technology-based instructional activities with high-level cognitive demands (75%), and maintained or/and increased level of cognitive demands of these tasks during Described Implementation (100%) and Expected Student Response (100%). Hence, they successfully demonstrated the ability to design technology-based instructional activities (similar to elementary level PSTs) and to adapt low-demand tasks into high-demand instructional activities (similar to middle level PSTs). This ability may be due to the fact that secondary level PSTs took methods courses during two consecutive semesters with a focus on cognitive demands, and this experience helped them to design technology based instructional activities with high-level mathematics tasks.
While considering overall results for technology based instructional activities, PSTs designed technology-based instructional activities with high-level cognitive demands, and the mean scores for Described Implementation and Expected Student Response were higher than the mean for Potential of the Task for all grade levels. This is important because PSTs planned technology activities to enhance students’ opportunities for thinking and reasoning, and students would often be required to provide explanations. This helps students to improve their learning and understanding of mathematics.

Many of tasks selected or created by PSTs scored high-level (52/68); indicating that PSTs planned to integrate high level cognitive demands tasks during instruction where students would have opportunities to engage with tasks in complex thinking and reasoning (score 3) and also requiring explanations (score 4). This is important because the selection or creation of high-level cognitive demand tasks for set-up (potential of the task) is key to encouraging students’ high-level mathematical thinking and reasoning and giving students opportunities to engage in cognitive processes at high level (Jackson, Garrison, Wilson, Gibbons, & Shahan, 2013; Stein, Grover & Henningsen, 1996). Selection of the task is important because it gives evidence about what teachers aim to do in teaching. In studies of mathematics teaching more generally, tasks at a level 4 occur in very low percentages (Boston & Wilhelm, 2015). Additionally, teachers observed by Sherman (2011) and the lesson plans of PSTs analyzed by Johnson (2012) indicated technology tasks and technology-based lessons with low cognitive demands in greater percentages than this present study.

For Described Implementation, five low-level tasks resulted in high-level cognitive demands, and this shows that PSTs aimed to engage students in complex thinking and reasoning, in creating meaning for mathematical procedures and concepts, and in exploring and
understanding the nature of mathematical concepts, procedures, and/or relationships. This is important because the demands of the tasks were increased during Described Implementation. Henningsen and Stein (1997) highlight the difficulties of maintaining high-level demands during implementation and how that affects students’ engagement in high levels of cognitive processing. Research on mathematics teachers’ use of high-demand tasks rarely shows an increase from task potential to task implementation (Boston & Wilhelm, 2015; Henningsen & Stein, 1997).

5.2.1.2 Technology activities created for Showcase portfolios. Almost all tasks (except one) scored 3 or 4, indicating that PSTs designed technology based instructional activities where students would be required to engage in complex mathematical thinking and reasoning and provide multiple representations (score of 3), and often provide explanations (score of 4). PSTs may have selected their best activity for the Showcase portfolio, because the Showcase portfolios are used by the university teacher educators to evaluate PSTs’ teaching performance. However, some of these tasks resulted in score a 2 for Implementation and Student Response. In these cases, PSTs did not maintain high-level cognitive demands and the students’ responses displayed computations or procedures (score of 2). Some tasks asked for an explanation (score of 4) but the students’ work did not indicate that students actually provided explanations; instead, the students’ response implicitly provided evidence of students’ mathematical thinking and reasoning (score of 3).

In summary, the results of research question one show that the way of using technology affects the maintenance or decline of the cognitive level of tasks. Similarly, Sherman (2011) categorized the ways teachers use technology into two main types; an amplifier and a reorganizer. An amplifier provides standard representations, the use of technology to display...
previously done-by-hand processes, and hence does not change students’ thinking. An amplifier
is used only to display the activity, so it does not change what students are thinking about
mathematical ideas during the instruction. On the other hand, a reorganizer has the power to
change students’ thinking and the cognitive demand of mathematical tasks. If PSTs used the
technological tools to provide the activity for only a visual representation of the contents or
demonstrating the activities, in some cases it was observed that the tasks were low-level for the
Described Implementation and Expected Student Response. For instance, one PST selected the
website (Figure 21), http://www.sheppardsoftware.com/mathgames/menus/fractions.htm. The
Potential of Task and Described Implementation were 2; however, Expected Student Response
scored a 1, because students were only asked to match the two representations of a fraction
and/or a visual representation of the fraction. This PST used the Internet website as an amplifier,
and the way of using this website decreased student’s opportunities for mathematical thinking.
Sherman (2011) made a similar conclusion that the cognitive demand was maintained during
implementation while using technology as both amplifier and reorganizer, however the cognitive
demands of the tasks declined (or were low-level) while using technology as an amplifier only.
To make comparisons between the present study results and previous studies, teachers were observed by Sherman (2011) and Polly (2014) and lesson plans of PSTs were analyzed by Johnston (2012). Participants of this study were able to select technology tasks with high cognitive demands in greater percentages than Sherman’s (2011) and Johnson’s (2012) participants, and similar percentages with Polly (2014). For example, the majority of technology tasks and instructional activities in these previous studies, such as Sherman (2011) and Johnston (2012), included low-level cognitive demands, and technology was used in instructional activities for display or “amplifier” purposes. Polly (2014) analyzed elementary school teachers’ use of technology during mathematics teaching, and the majority of instructional activities in the study featured high-level demands (71%), especially procedures with connection (277 out of 414). In this present study, elementary and secondary level PSTs mainly selected tasks with high-level demand.

Sherman (2011) concluded in his study, “technology did not play a significant role in maintaining the cognitive demand during implementation for most of these teachers, as this
rarely occurred” (p.190). However, this present study and Polly (2014) found a positive relationship between technology used and the level of cognitive demands of mathematical tasks. Subjects in this present study were more successful at planning technology-based instructional activities with high demands than in Sherman’s study, perhaps because PSTs were trained on how to select and implement cognitively demanding tasks throughout the mathematics methods course. Hence, PSTs in this study had opportunities to develop strong PCK, and this increased their TPACK (technological pedagogical content knowledge) to effectively design technology activities for the teaching of mathematics.

Through analysis of technology activities and Showcase Portfolios created by PSTs, the present study results indicate that PSTs selected technology resources and designed technology-based instructional activities with high-level cognitive demands for teaching specific mathematical content. In terms of the implications for teacher education, these results suggest that to support students’ high-level mathematical thinking with using technology, PSTs should be trained on using technology as not only to demonstrate or display the lesson (e.g., as an amplifier only) but also to support students’ mathematical thinking through the use of cognitively challenging tasks (e.g., as a reorganizer or reorganizer-and-amplifier).

A focus on cognitive demands throughout mathematics methods courses may be productive in supporting PSTs to design instructional activity to support students’ mathematical thinking at a high-level. It may be difficult to add technology into lesson planning, because many methods courses provide strong pedagogical content knowledge (PCK), but not technology knowledge. However, since some PSTs decreased cognitively challenging tasks during lessons in their student teaching classrooms, teacher education should also create more opportunities for
PSTs to demonstrate their knowledge into practice, and they should receive supports for implementing technology-based tasks during field experiences and student teaching.

5.2.2 Level of Teaching Innovation (LoTi).

This study also examined the pre-service teachers’ (PST) level of technology implementation using LoTi Digital-Age framework, which examines the levels of technology implementation based on Personal Computer Use (PCU), Current Instructional Practices (CIP), and Level of Technology Implementation (LoTi). The results indicated that PSTs’ LoTi level was 4a (Integration-Mechanical), which indicates that the PST either supports or implements the instructional uses of technology in a mechanical manner in a classroom setting. The CIP intensity level was level 5, which implies PSTs’ future instructional practices tend to be more toward a student-directed approach and leading to higher student achievement on student achievement scores. The PCU intensity level was level 4, which means PSTs will demonstrate moderate to high fluency by using digital-age tools and resources to support instructional strategies and curriculum for student learning in their future classroom. Based on the results of this study, participants of this present study were comfortable with their own personal computer use and were capable of solving most hardware and software problems. More importantly, PSTs’ learner-centered approach is at a high level, since PSTs’ perceptions of integration technology are very important and play a significant role for successful teaching in their future classrooms.

The LoTi Digital-Age score is important for teachers and even PSTs, because levels of teachers’ classroom technology use are measured and teachers can get feedback about how technology is used. Some studies highlighted the importance of LoTi scores to help teachers to be aware of their comfort level of using technology in the classroom (such as Laney, 2002; Stoltzfus, 2006). In this study most PSTs (60%) were at a LoTi level of 4 and above, and only
25% of PSTs at the level 1 or 2. Moersch (1995) found that 69% of educators were at the level of use of 1 or 2, and only 14% of educators were at level of 4a and above. In another study, Griffin (2003) found that only 24% of educators at a technological level of use of 1 or 2 (similar to the results of this study) and 32% at the target level 4a and above, which is substantially less than the PSTs’ at or above level 4a in the current study.

The high percent of PSTs at a level 4a or above in this study is important because Berkeley-Jones (2012) found significant differences between mathematics teachers’ LoTi scores and students’ math scores. Students’ mean scores of mathematics achievement who had teachers with LoTi level 4 (integration) was higher than those with teachers whose LoTi level is 2 (exploration). This result shows that students taught by teachers who had higher LoTi levels might have higher math achievement scores than students taught by teachers who had lower LoTi levels. The results of this study indicated that PSTs were doing very well with their own personal computer use, troubleshooting, identification of instructional practices that reflected a learner-based curriculum design, and effective technology implementation. Based on the research presented here, PSTs in this study may be better equipped to support students’ learning in mathematics.

No significant difference was found in PSTs’ Personal Computer Use (PCU), Current Instructional Practices (CIP), and Level of Technology Implementation (LoTi), based upon grade level. Nevertheless, other prior research has found significant differences between secondary and elementary teachers based upon LoTi scores, with mixed results. Secondary teachers’ LoTi scores were higher than elementary teachers in one study (Lemoine, 2007) and lower than elementary teachers in another study (Griffin, 2003). Another study (Barron, Kemker, Harmes. & Kalaydjian, 2003) indicated that elementary school teachers used technology such as
computers in problem solving more frequently than middle or high school teachers. Similarly, Bebell et al. (2004) found that middle and high school teachers used technology more frequently for grading purpose than elementary teachers, and elementary teachers used technology more frequently for highlighting the lesson than middle and high school teachers. The results of this study indicate that PSTs at all levels demonstrated the ability to use technology in ways that supports students’ learning of mathematics, were comfortable in their use of technology, and had a student- or learner-centered focus for using technology in the classroom. Hopefully, this implies that the PSTs will be likely to use technology in ways that supports students’ learning in their future classrooms.

5.2.3 Cognitive Demand and Level of Teaching Innovation.

By analyzing the relationship between IQA rubrics scores (Potential of the Task, Describe Implementation, and Expected Student Response) and each LoTi-Digital Age levels (PCU, CIP, and LoTi), the researcher discovered that the LoTi Digital-Age scores did not correlate with the IQA rubrics. PSTs’ LoTi Digital-Age scores did not have any significant impact for their selection of mathematics tasks. This may indicate that other factors besides teachers’ use of technology (such as PSTs’ strong pedagogical content knowledge, available various technologies, or method courses in which PSTs had opportunity to practice their knowledge) impacted and enhanced their ability to create high-level instructional activities.

5.3 Case Studies

This section provides case studies of pre-service teachers selected from the group of participants. All data collected from that participant will be identified by a pseudonym, and the pseudonym is used throughout this chapter. The researcher did not actually observe the lessons taught by PSTs, and it is important to note that the comments and descriptions in this section are
based on lesson activities and/or samples of students’ work (for Showcase Portfolios only). The cases presented in this section include: 1) how PSTs used the same task differently; 2) how PSTs maintained high level cognitive demands; 3) how PSTs’ reduced high-level cognitive demands; and 4) how PSTs increased high-level cognitive demands.

5.3.1 Integration of same task differently

The first case illustrates how the same technology task is described and used differently in different lesson activities. This task is retrieved from http://illuminations.nctm.org/Activity.aspx?id=3540 and is illustrated in Figure 22.

**Figure 22.** Screenshot of Bobbie Bear activity. (NCTM Illuminations, n.d.-c).

Teachers can use this “Bobbie Bear” activity in a Pre-K to fifth grade classroom to help students learn about using counting strategies to see how many different combinations of outfits they can make for Bobbie Bear. In this activity, the students can learn about combinations, addition, or multiplication by creating the different combinations of outfits. The customized
settings vary from grade to grade; the only thing that is adjusted is the amount of shirts and pants. The teacher can customize how many different pairs could be made and choose the different levels of difficulties the students are using. The directions given in the activity are, “Bobbie Bear is planning a vacation and wants to know how many outfits can be made using different colored shirts and pants. How many outfits can you make?”

This activity also provides five questions the teacher could use for a source of exploration with the children to allow them to broaden their knowledge (however, there is not a lesson plan, suggested activity, or any handouts the correspond with the applet).

- How many outfits do you think can be made?
- How do you know when you have made all the outfits?
- If you are missing an outfit, how do you find out which one it is?
- How can you organize your work to make answering these questions easier?
- Try your strategy for more shirts and pants using the Customize button.

The Potential of the Task scores a 3, since students are asked questions that provide students opportunities to identify the combination of different colored shirts and pants. The task has potential to engage students in creating meaning for mathematical concepts and procedures. The task does not require an explanation or evidence of students’ reasoning and understanding (e.g., generalizing a short-cut or explaining why repeated addition, multiplication, a tree diagram, or the Fundamental Counting Principle is an appropriate strategy), so the task does not score a 4.

Described Implementation and Expected Student Response scores can be different based on how PSTs describe the implementation of the task or technology within the instructional
activity. Below the researcher gives examples from two cases of how PSTs implement the same task in different ways and how they expect different student responses.

The first PST is referred to as Zach, and he was enrolled in the PK-4 Numeracy Pedagogy course (e.g., elementary mathematics methods course) during Fall 2014. Zach incorporated the National Council of Teachers of Mathematics (NCTM) Illumination website on the SmartBoard to demonstrate “Bobbie Bear” activity. The reason for selecting this website was to address important mathematical content, because the activity that he selected provides a lot of activities with addition. Zach mentioned the importance of addition concept for children at a young age to learn because “it is the foundation of a lot of different mathematical concepts they will encounter later in life.”

In this activity, students learn about combinations and what they mean by adding up the different combinations of outfits. He described implementation of the task as the teacher starting the lesson by explaining what different combinations are and giving examples of different combinations. Then he explains the implementation as follows:

When the class has a good foundation the teacher can poll the class on how many different outfits they will be able to make for Bobbie Bear. After the teacher records the class estimate, he or she can then call on students to come up to the board to drag the two pieces of clothing on to the bear. The teacher will then continue this until the class agrees that no more combinations can be made. Next, the teacher will be able to compare the class’s estimate to the amount of outfits they were able to make. The teacher will then be able to check the students answer and the program will tell the class whether they were right or not.
He described implementation at a procedural level, and the score of *Described Implementation* is a 2. The implementation requires students to focus on correctly executing a procedure to obtain a correct answer, but not to explore, build meaning, explain or support their ideas. In fact, the described implementation does not make any connections to addition. The score of *Student Response* is a 1, because students are only asked to provide a brief numerical answer and find the correct amount of combinations by typing numbers in the box. Zach decreased the level of the cognitive demands from high-level to low-level for *Described Implementation* and *Expected Student Response*.

The second PST is referred to as Emily, and she was enrolled in the PK-4 Numeracy Pedagogy course during Spring 2015. In her activity, the children could work together on an iPad or a computer to do the “Bobbie Bear” activity. She selected this activity because “this would be a fun interactive way for the students to apply their probability and computing possibilities knowledge in a fun and exciting way using technology”. During the implementation she wants the students to share out their different strategies for solving these types of problems. Also, this activity promotes active learning, and she expressed that this activity could also be used as an informal assessment of the children’s knowledge: “While the students were playing this game I could formatively assess them by walking around the room and seeing different strategies the students are using within their problem solving”.

Emily described implementation at a “procedures with connections” level, and the score of *Described Implementation* is 3, because students engage in creating meaning for mathematical procedures and concepts, but are not explicitly required to produce explanations (e.g., to explain why 3 shirts and 4 pants result in 4 x 3 or 12 outfits), so it does not score a 4. *Expected Student Response* also scores a 3, because students are required to provide evidence of mathematical
thinking and reasoning such as multiple strategies, but no explanation is required. Emily maintains the level of the cognitive demands for Described Implementation and Expected Student Response.

As described in Chapter 2, lesson plans are part of the intended curricula, and teacher thinking about how lessons should be taught can be reflected in lesson plans (Remillard, 1999; Stein, Remillard, & Smith, 2007). In this case, both PSTs selected the same task using the same technology activity (intended curriculum) but they aimed to enact the activity in different ways (enacted curriculum).

5.3.2 Maintenance of High-Level Cognitive Demands.

This case illustrates how PSTs maintained the level of cognitive demands of mathematical tasks during implementation and expected student response. The PST is referred to as Dora, and she was enrolled in Teaching Secondary Mathematics (e.g., secondary mathematics methods course) during Spring 2015. She designs an activity that involves the use of virtual Algebra tiles in a high school level (Grades 9-12) Algebra class. Dora selected Algebra tiles that are mathematical manipulatives created to allow students to view symbolic representations through concrete models. Algebra tiles give students another way to solve algebraic problems other than just abstract manipulation. Algebra tiles can be used for a variety of mathematical concepts, including adding and subtracting integers, multiplying polynomials, factoring, and completing the square.

The task is to use Algebra tiles to solve linear equations, and she selected an applet from the NCTM illuminations website (http://illuminations.nctm.org/activity.aspx?id=3482), shown in Figure 23. Dora believes that this Internet applet is great for students because it gives them a
chance to use technology for a mathematical concept instead of using pencil and paper, and allows the students to visually see what they are doing to solve an equation.

Figure 23. Screenshot of NCTM illuminations website. (NCTM Illuminations, n.d.-d).

The directions for the task are: Build your model and solve an equation. The website also provides the list of what students can do with applet: “Use tiles to represent variables and constants, learn how to represent and solve algebra problem. Solve equations, substitute in variable expressions, and expand and factor. Flip tiles, remove zero pairs, copy and arrange, and make your way toward a better understanding of algebra”. Potential of the Task scores a 3, since students are asked to build their model. The task has potential to engage students in creating meaning for mathematical concepts and procedures. Dora described implementation step by step:
1. Start with an equation

2. Use the pointer tool and place the correct pieces in the workspace. After you build the model of the given problem, check your answer to move on to the next step. Only tile type, tile quantity, and workspace area are checked, not the way in which tiles are arranged.

3. Try eliminating the necessary tiles to create zero pairs. Remember, what you do to one side, you must do to the other side!
4. After you solve the problem, check your answer.

5. Practice: Solve the following equations using the Algebra tiles:

a) $4x - 1 = 2x + 3$

b) $2x + 2 = 4$

c) $4x - 3 = 5$

d) $5x - 5 = 4x + 2$

*Figure 24. Screenshot of Dora lesson plan*
Dora planned to ask three questions after the students practiced above problems. These questions are:

1) What is the goal for solving equations?

2) How do the Algebra tiles allow you to better visualize the concept of zero pairs?

3) Explain the phrase “whatever you do to one side, you must do the exact same thing to the other side”?

Dora described implementation at the procedures with connection level, requiring complex thinking. The score of Described Implementation is 4, because students are required to explain and understand the nature of mathematical concepts and procedures. Expected Student Response also scores a 4, because students are required to provide evidence of mathematical thinking and reasoning such as multiple strategies, and also explanation is required. The cognitive demands of the original task were high level, and Dora’s described implementation maintained the high level demands and increased the score level from 3 to 4 for Described Implementation and Expected Student Response.

This case is an example of the maintenance of high-level task demands for described implementation and expected student response. This case is important because maintaining the cognitive demand of instructional tasks through the task implementation resulted higher student achievement. Stein and Lane (1996) described the patterns of set up, implementation, and student learning, as shown in Figure 25. High-level cognitive demands at task set-up and maintaining high level of cognitive demands during implementation results in high level student learning.
5.3.3 Increasing Low-Level Cognitive Demands

In this case, how PSTs increased level of the cognitive demands of mathematical tasks during implementation and expected student response is discussed. This activity was created by PSTs (working in a group of 3) in the Teaching Middle Level Mathematics (middle level mathematics methods) course during Spring 2015. This activity shows how PSTs increased low-level mathematics task during Described Implementation and Expected Student Response with high-level cognitive demands. It is a SmartBoard activity, which is called “Perimeter Patch” and revolves around the topics of area and perimeter. The activity (see Figure 26) was selected from http://exchange.smarttech.com/details.html?id=a06612eb-f7ec-43b4-9ae8-3e5b9784a7f1.
This group selected SmartBoard as a technological tool because “it allows students to complete activities while having a visual representation, and they are also able to interact with the SmartBoard throughout the lesson as they work to grasp the concepts of area and perimeter. This SmartBoard lesson is a colorful and fun way to teach area and perimeter to students using technology with which they will be able to interact. Also, this activity can help students to apply the topics of area and perimeter to real life situations and understand why they are useful.”

The task is “Each pumpkin patch is (9) feet long and (6) feet wide. What is the area of each patch in square feet?” The task asks 8 questions similar in format (with different numbers for length and width) and provides space for students to “Write your answers here.” Potential of the Task scores a 2, since it does not require students to make connections to the concepts or meaning of content (e.g.,

---

Figure 26. Screenshot of middle level PSTs’ lesson activity. (Smart Exchange, n.d.)
students could produce the answers procedurally or from memory without making any connections to area, length, width, or square feet) and the focus of the task is writing the correct answer.

The group of PSTs described implementation as:

The next SmartBoard slides in this activity will examine pumpkin patches that have different areas but the same perimeter. Then, we will look at pumpkin patches that have the same area, but different perimeter. Students will be able to see how area and perimeter are not necessarily dependent on each other and just because two objects have the same perimeter, they do not have to have the same area, and vice versa.

The next part of the SmartBoard lesson will be a problem for students to solve. I will show an empty pumpkin patch and say: “If each block of the pumpkin patch counts for one square yard, and 4 pumpkins can fit in each square yard, then how many pumpkins can fit in the patch if the area of the pumpkin patch is 25 blocks?” The blank pumpkin patch will be shown on the SmartBoard and I will allow students to come up to the SmartBoard and drag and drop pumpkins into each of the squares as they work to solve the problem. Students can also use manipulatives, given at each table, to help solve the problem. Some students may be able to develop a formula and work out the problem on their worksheets. Once students have solved the problem on their own, we will solve it on the Smartboard and demonstrate the several ways to find the answer.

The group of PSTs described implementation at a procedure with connections level, and the score of Described Implementation is 3. The group of PSTs wants their students to apply several strategies and to work with manipulatives to solve the task. The questions regarding perimeter and area require students to engage with and understand mathematics concepts. Expected Student response also scores a 3, because they were asked to develop a formula or use multiple strategies or diagrams to find the correct answer and support their understanding of perimeter and area.
This case shows how teachers and PSTs can raise the cognitive demand of the task during instruction. This case is important because enacting this task with high level cognitive demands results in different types of students’ thinking and creates opportunities for higher order thinking. Additionally, implementing tasks with higher cognitive demand to students during instruction can lead to students’ higher achievement and better conceptual understanding.

5.3.4 Decline of High-Level Cognitive Demands.

This case illustrates how PSTs decreased the level of cognitive demands of mathematical tasks during implementation and expected student response from high level to low-level. The PST is referred to as Carrie, and she completed her student teaching in during Fall 2014. This case is based on a task, reflection on implementation, and samples of students’ work submitted as part of her student teaching Showcase Portfolio.

This activity is creating an equation for a quadratic relationship, and is designed for an Honors Algebra 2 class for grade 9 and 10. The aim of this task is to discover how to use the graphing calculator to derive a quadratic equation that passes through three given points. Using the graphing calculator is not only helping students to create the equation but also to understand how they will be able to use this knowledge when working with polynomials.

The task is shown in Figure 27a and the calculator instructions in Figure 27b. As mentioned in Chapter 3, a mathematical task can consist of a single problem or exercise (simple or complex and multi-step) or a set of related problems or exercises that focus students’ attention on a particular mathematical idea (Stein, Smith, Henningsen, & Silver, 2009). This set of related problems is scored as one task. Potential of the Task scores a 4, since it requires students to engage in complex mathematical thinking and provide an explanation. The last question is asked “Calculate the revenue if the t-shirts were to be sold for $4 each, explain what this would mean”, and this question makes the task score a 4.
4.10 Warm-Up

The school store at Norwin sells T-shirts among other items. The table shows data from the last four years for the price charged for a T-shirt, x, and the total revenue earned from selling them, y.

<table>
<thead>
<tr>
<th>X</th>
<th>8</th>
<th>10</th>
<th>12</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>1180</td>
<td>1450</td>
<td>1675</td>
<td>1550</td>
</tr>
</tbody>
</table>

1st Observe the table and predict what price should be used to maximize revenue.

2nd Use a graphing calculator to find the best-fitting quadratic model for the data in standard form. (see front board for instructions)

3rd Plot the scatter plot on the calculator

4th Graph the best-fitting quadratic on the calculator

5th Calculate the price of the t-shirts that would maximize the revenue

6th Calculate the total number of t-shirts sold when maximizing the revenue

7th Calculate the revenue if the t-shirts were to be sold for $4 each, explain what this would mean.
<table>
<thead>
<tr>
<th>x</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>14</td>
<td>20</td>
<td>25</td>
<td>30</td>
</tr>
</tbody>
</table>

```
EDIT CALC TESTS
1:1-Var Stats
2:2-Var Stats
3:Med-Med
4:LinReg(ax+b)
5:QuadReg
6:QuadReg
7:QuadReg
8:QuadReg
```

```
QuadReg
a = ax + bx + c
a = 24.6826
b = 6.99873
```

```
QuadReg

```
```
Plot1 On
1: Lt 1
2: Lt 1
3: Lt 1
```
Carrie started the class handing out the warm-up problem of the day, and gave students the worksheet with the directions for the graphing calculator and the screen shots on it. This helps students to reference as they work through the problem. As the students work through this worksheet, Carrie walked around the classroom to give any assistance if required. She was planning to create opportunities for the students to use critical thinking and also problem solving skills.

However, student response is a score of 2, because students only give one–word descriptions or just solve the task instead of giving an explanation. Students were expected to plot the scatter plot on the calculator, however there was no evidence on student’s worksheet that
shows students’ work with the graphing calculators. The score of 2 is given for implementation also, because Carrie aimed to use graphing calculator to teach an equation for a quadratic, however she describes that limited access to technology in her class made incorporating the graphing calculator into the lesson very challenging. For students who did not have their own graphing calculator, Carrie was able to secure laptops for them to use and if necessary, they used a website with a graphing calculator at home. Some students were not able to use graphing calculators in the classroom so they did not engage in high-level thinking and reasoning during the lesson.

In this case, the technology would have served as a reorganizer but limited access to the technology kept students from being able to make the connections between representations that would have been illustrated by the technology. Also, as Stein and Lane (1996) stated, the decline of the level of cognitive demands during implementation resulted in moderate students learning.

These cases provide examples of how PSTs aimed to implement the same task differently, and to maintain, decrease, and increase the level of cognitive demands during described implementation were discussed. These cases can help teacher educators and PSTs be aware of how to design and enact instructional activities and implement technology within the context of mathematics for students’ higher mathematics learning and success.

5.4 Recommendations and Directions for Future Research

The recommendations that came out of this study can be used as a guide in mathematics teacher preparation programs. The results of this study can provide a framework (e.g., attention to cognitive demands) and examples that mathematics teacher educators can use in order to prepare PSTs to use technology to support students’ high level mathematical thinking. While this study focused on PSTs, attending to cognitive demands when planning instructional activities is
also a useful framework for classroom teachers. Similarly, while this study focused on the content area of mathematics, the results of the study have the potential to guide education courses (e.g., methods course in any subject or certification level) or instructional technology courses in universities that are preparing PSTs to incorporate technology into instruction in ways that support students’ learning. It is important to prepare PSTs to use technological tools in ways that support students’ high-level thinking in any content-area. Teacher educators should be aware of the importance of attending to cognitive demands when using technology as a teaching and learning tool, and prepare future teachers based on this goal. The study may provide the resources and/or materials for mathematics teacher educators to consider different levels of cognitive demands of tasks in and beyond mathematics.

Several studies conducted research about the influence of the use of technology on student achievement (Bebell & Kay, 2010; Bebell & O’Dwyer, 2010; Shapley, Sheehan, Maloney, & Caranikas-Walker, 2010; Suhr, Hernandez, Grimes, & Warschauer, 2010) and found that the use of technology had a positive influence on student achievement. Students in today’s classroom are digital natives because they have grown up in a technology-based world (Prensky, 2001). Today’s PSTs have the ability of integrating technology in their lesson plans and indicate that they are open this idea, but need guidance to help them to integrate technology effectively. This guidance is a combination of knowledge of technology, pedagogy, and content. Teacher education programs must address not only pedagogical and content knowledge, but also use of technology within specific pedagogy (e.g. learner-centered classrooms) and content (e.g., mathematics). Method courses deliver pedagogical content knowledge to future teachers, and should also provide opportunities for PSTs to increase their technology knowledge within the context of pedagogical and content-related goals. Mathematics teacher educators should provide
support for PSTs to effectively design technology-based instruction, enable their PSTs to appropriately integrate technology into their lesson plans, and provide experiences for PSTs to use technology in field experience or student teaching classrooms. The results of this study suggest that one productive pathway would be to provide guidance to PSTs on how to maintain or increase the level of cognitive demands.

Classrooms are complex environments, especially for PSTs. More opportunities are needed for prospective teachers to design and implement technology-based instructional activities that support students’ learning. Specifically, PSTs need opportunities to teach these activities during teacher preparation programs, field experiences, and student teaching in order to be prepared and comfortable to incorporate technology in their future classrooms. PSTs’ use of technology is not likely to be successful if it is not practiced prior to and during student teaching. For example, PSTs can practice through creating and delivering technology-based instructional activities, as a combination of technology, pedagogy, and content knowledge. Hence, teacher education program should create opportunities for PSTs to integrate technology within methods courses and within the student teaching placements. The ultimate goal is that PSTs will transfer this knowledge into their future classroom settings.

5.5 Recommendations

The present study only analyzed PSTs’ technology activities and Showcase Portfolios, so additional research is needed to observe PSTs in their student teaching classrooms to analyze how technology activities are actually implemented during mathematics instruction and how it may vary in the instructional setting. Further research may involve an observation approach and interview with PSTs and that might provide additional understandings of how technology is used in the classroom.
This study also focused on pre-service teachers (PSTs). Boston and Smith (2009) have designed professional development about the selection and enactment of high-level tasks, and the result showed it is effective. This professional development could be extended to focus on how mathematics tasks are selected and implemented and how students engage with tasks during the instruction when tasks include the development and integration of the use of technology. Future research could examine classroom teachers’ use of technology before and after the professional development, hence replicating the current study with classroom teachers.

5.6 Limitations

The population of this study is pre-service teachers in the PK-4 program, Middle Level program (grades 4-6) and Secondary Mathematics (grades 7-12) program in 2014-2015 at a mid-sized private university in the northeastern United States. The sample size for survey, n=20, and for Showcase portfolio, n=14, are relatively small. There are some reasons of limited participation in the survey. Because consent was obtained at the end of the semester, many of PSTs focused on their final exams or papers instead of the completing the LoTi Digital-Age survey. Also the LoTi organization does not offer a paper-and-pencil survey, so the researcher could not offer them to complete the survey during their method class.

The results of this study may be unique to this specific population (i.e., PSTs in a specific teacher preparation program, taking similarly-designed mathematics methods courses, at the same University), and the results of this study may not be generalizable to other populations. Also, this study uses a non-probability sample, which limits generalization.
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### Appendix A

#### Academic Rigor 1: Potential of the Task

<table>
<thead>
<tr>
<th>Instructional Quality Assessment (IQA) in Mathematics Rubrics (Boston, 2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AR1: Potential of the Task</strong></td>
</tr>
<tr>
<td><strong>High-Level Cognitive Demands</strong></td>
</tr>
</tbody>
</table>
| The task has the potential to engage students in exploring and understanding the nature of mathematical concepts, procedures, and/or relationships, such as (from Stein, et al., 2009):
| • Doing mathematics: using complex and non-algorithmic thinking (i.e., there is not a predictable, well-rehearsed approach or pathway explicitly suggested by the task, task instructions, or a worked-out example); or
| • Procedures with connections: applying a broad general procedure that remains closely connected to mathematical concepts.
| The task must explicitly prompt for evidence of students’ reasoning and understanding. For example, the task MAY require students to:
| • solve a genuine, challenging problem for which students’ reasoning is evident in their work on the task;
| • develop an explanation for why formulas or procedures work;
| • identify patterns;…justify generalizations based on these patterns;… |
| **Low-Level Cognitive Demands** |
| The potential of the task is limited to engaging students in using a procedure that is either specifically called for or its use is evident based on prior instruction, experience, or placement of the task…. The task does not require students to make connections to the concepts or meaning underlying the procedure being used… (e.g., practicing a computational algorithm).
| The potential of the task is limited to engaging students in memorizing or reproducing facts, rules, formulae, or definitions… |
# Appendix B

## Academic Rigor 2: Implementation of the Task

<table>
<thead>
<tr>
<th>Implementation of the Task (Boston, 2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students engage in using complex and non-algorithmic thinking or by exploring and understanding the nature of mathematical concepts, procedures, and/or relationships.*</td>
</tr>
</tbody>
</table>
| Students engage in complex thinking or in creating meaning for mathematical procedures and concepts BUT the problems, concepts, or procedures do not require the extent of complex thinking as a “4”;  
OR  
The “potential of the task” was rated as a 4 but students only moderately engage with the high-level demands of the task.* |
| Students engage with the task at a procedural level. Students apply a demonstrated or prescribed procedure. Students may be required to show or state the steps of their procedure, but are not required to explain or support their ideas. Students focus on correctly executing a procedure to obtain a correct answer. |
| Students engage with the task at a memorization level. Students are required to recall facts, formulas, or rules (e.g., students provide answers only);  
OR  
The task requires no mathematical activity. |
| N/A | Reason: |
### Appendix C

**Academic Rigor 3: Expected Student Response**

<table>
<thead>
<tr>
<th>Expected Student Response (Boston, 2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The expected student response provides evidence of students’ mathematical thinking and reasoning (such as multiple representations or strategies, diagrams, etc.) <strong>AND</strong> an explanation is explicitly required.</td>
</tr>
<tr>
<td>The expected student response provides evidence of students’ mathematical thinking and reasoning (such as multiple representations or strategies, diagrams, etc.) <strong>BUT</strong> no explanation is required.</td>
</tr>
<tr>
<td>The expected student response is a computation or procedure,…or procedural explanation such as “Show your work.” Students are not required to demonstrate connections to mathematical concepts in their response to the task, even if task itself provided opportunities for connections.</td>
</tr>
<tr>
<td>Students <em>are asked to</em> provide brief numerical or one-word answers (e.g., fill in blanks, provide only the result or answer).</td>
</tr>
<tr>
<td><strong>N/A</strong></td>
</tr>
</tbody>
</table>

Reason:
Appendix D

The Levels of Technology Implementation (LoTi) Framework

Level 0 – Non-use

Technology-based tools (e.g., computers) are either (a) completely unavailable in the classroom, (b) not easily accessible by the classroom teacher, or (c) there is a lack of time to pursue electronic technology implementation. Existing technology is predominantly text-based (e.g., ditto sheets, chalkboard, overhead projector).

Level 1 - Awareness

The use of technology-based tools is either (a) used almost exclusively by the classroom teacher for classroom and/or curriculum management tasks (e.g., taking attendance, using grade book programs, accessing email), (b) used to embellish or enhance teacher-directed lessons or lectures (e.g., multimedia presentations) and/or (c) is one step removed from the classroom teacher (e.g., integrated learning system labs, special computer lab pull-out programs, central word processing labs).

Level 2 - Exploration

Technology-based tools supplement the existing instructional program (e.g., tutorials, educational games, basic skill applications) or complement selected multimedia and/or web-based projects (e.g., internet-based research papers, informational multimedia presentations) at the knowledge/comprehension level. The electronic technology is employed either as extension activities, enrichment activities, or technology-based tools and generally reinforces the content under investigation.
**Level 3 - Infusion**

Technology-based tools including spreadsheet and graphing packages; multimedia and desktop publishing applications; and the internet complement selected instructional events or multimedia/web-based projects at the analysis, synthesis, and evaluation levels. Though the learning activity may or may not be perceived as authentic by students, emphasis is placed on using a variety of thinking skill strategies (e.g., problem-solving, decision-making, experimentation, scientific inquiry) to address the content under investigation.

**Level 4a - Integration (Mechanical)**

Technology-based tools are integrated in a mechanical manner that places heavy reliance on prepackaged materials, outside resources, and/or interventions that aid the teacher in the daily management of their operational curriculum. Technology is perceived as a toll to identify and solve authentic problems as perceived by the students relating to an overall theme/concept. Emphasis is placed on student action and/or issues resolution that requires higher level of cognitive processing and in-depth examination of the content.

**Level 4b - Integration (Routine)**

Technology-based tools are integrated in a routine manner whereby teachers can readily design and implement learning experiences (e.g., units of instruction) that empower students to identify and solve authentic problems relating to an overall theme/concept using the school’s available technology with little or no outside assistance. Emphasis is placed on student action and/or issues resolution that requires higher levels of student cognitive processing and in-depth examination of the content.
**Level 5 - Expansion**

Technology access is extended beyond the classroom. Teachers actively elicit technology applications and networking from outside sources to expand student experiences directed at problem-solving, issues resolution, and student activism. The complexity and sophistication of the technology-based tools used are now commensurate with (a) the diversity, inventiveness, and spontaneity of the teacher’s experiential-based approach and (b) the students’ level of complex thinking and in-depth understanding of the content at hand.

**Level 6 - Refinement**

Technology is perceived as a process, product, and/or tool for students to find solutions related to an identified “real-world” problem or issue of significance to them. Technology provides a seamless medium for information queries, problem-solving, and/or product development. The classroom content emerges based on the needs of the learner according to his/her interests, needs, and/or aspirations and is supported by unlimited access to the most current computer applications and infrastructure available.

(Learning Quest, 2011)
Appendix E

The Personal Computer Use (PCU) Framework

*Intensity Level 0*

A PCU Intensity Level 0 indicates that the participant does not feel comfortable or have the skill level to use computers for personal use. Participants at Intensity Level 0 rely more on the use of overhead projectors, chalkboards, and/or traditional paper/pencil activities than using computers for conveying information or classroom management tasks.

*Intensity Level 1*

A PCU Intensity Level 1 indicates that the participant demonstrates little skill level with using computers for personal use. Participants at Intensity Level 1 may have a general awareness of various technology-related tools such as word processors, spreadsheets, or the internet, but generally are not using them.

*Intensity Level 2*

A PCU Intensity Level 2 indicates that the participant demonstrates little to moderate skill level with using computers for personal use. Participants at Intensity Level 2 may occasionally browse the internet, use email, or use a word processor program; yet, may not have the confidence or feel comfortable troubleshooting simple "technology" problems or glitches as they arise. At school, their use of computers may be limited to a grade book or attendance program.

*Intensity Level 3*

A PCU Intensity Level 3 indicates that the participant demonstrates moderate skill level with using computers for personal use. Participants at Intensity Level 3 may begin to become
"regular" users of selected applications such as the internet, email, or a word processor program. They may also feel comfortable troubleshooting simple "technology" problems such as rebooting a machine or hitting the "Back" button on an internet browser, but rely on mostly technology support staff or others to assist them with any troubleshooting issues.

Intensity Level 4

A PCU Intensity Level 4 indicates that the participant demonstrates moderate to high skill level with using computers for personal use. Participants at Intensity Level 4 commonly use a broader range of software applications including multimedia (e.g., Microsoft PowerPoint, HyperStudio), spreadsheets, and simple database applications. They typically have the confidence and are able to troubleshoot simple hardware, software, and/or peripheral problems without assistance from technology support staff.

Intensity Level 5

A PCU Intensity Level 5 indicates that the participant demonstrates high skill level with using computers for personal use. Participants at Intensity Level 5 are commonly able to use the computer to create their own web pages, produce sophisticated multimedia products, and/or effortlessly use common productivity applications (e.g., Microsoft Excel, FileMaker Pro), desktop publishing software, and web-based tools. They are also able to confidently troubleshoot most hardware, software, and/or peripheral problems without assistance from technology support staff.

Intensity Level 6

A PCU Intensity Level 6 indicates that the participant demonstrates high to extremely high skill level with using computers for personal use. Participants at Intensity Level 6 are
sophisticated in the use of most, if not all, multimedia, productivity, desktop publishing, and web-based applications. They typically serve as "troubleshooters" for others in need of assistance and sometimes seek certification for achieving selected technology-related skills.

Intensity Level 7

A PCU Intensity Level 7 indicates that the participant demonstrates extremely high skill level with using computers for personal use. Participants at Intensity Level 7 are expert computer users, troubleshooters, and/or technology mentors. They typically are involved in training others on any technology-related task and are usually involved in selected support groups from around the world that allow them access to answers for all technology-based inquiries they may have.

(Learning Quest, 2011)
Appendix F

The Current Instructional Practices (CIP) Framework

**Intensity Level 0**

A CIP Intensity Level 0 indicates that one or more questionnaire statements were not applicable to the participant's current instructional practices.

**Intensity Level 1**

At a CIP Intensity Level 1, the participant's current instructional practices align exclusively with a subject-matter based approach to teaching and learning. Teaching strategies tend to lean toward lectures and/or teacher-led presentations. The use of curriculum materials aligned to specific content standards serves as the focus for student learning. Learning activities tend to be sequential and uniform for all students. Evaluation techniques focus on traditional measures such as essays, quizzes, short-answers, or true-false questions. Student projects tend to be teacher-directed in terms of identifying project outcomes as well as requirements for project completion.

**Intensity Level 2**

Similar to a CIP Intensity Level 1, the participant at a CIP Intensity Level 2 supports instructional practices consistent with a subject-matter based approach to teaching and learning, but not at the same level of intensity or commitment. Teaching strategies tend to lean toward lectures and/or teacher-led presentations. The use of curriculum materials aligned to specific content standards serves as the focus for student learning. Learning activities tend to be sequential and uniform for all students. Evaluation techniques focus on traditional measures such as essays, quizzes, short-answers, or true-false questions. Student projects tend to be teacher-
directed in terms of identifying project outcomes as well as requirements for project completion.

**Intensity Level 3**

At a CIP Intensity Level 3, the participant supports instructional practices aligned somewhat with a subject-matter based approach to teaching and learning: an approach characterized by sequential and uniform learning activities for all students, teacher-directed presentations, and/or the use of traditional evaluation techniques. However, the participant may also support the use of student-directed projects that provide opportunities for students to determine the "look and feel" of a final product based on specific content standards.

**Intensity Level 4**

At a CIP Intensity Level 4, the participant may feel comfortable supporting or implementing either a subject-matter or learning-based approach to instruction based on the content being addressed. In a subject-matter based approach, learning activities tend to be sequential, student projects tend to be uniform for all students, the use of lectures and/or teacher-directed presentations are the norm as well as traditional evaluation strategies. In a learner-based approach, learning activities are diversified and based mostly on student questions, the teacher serves more as a co-learner or facilitator in the classroom, student projects are primarily student-directed, and the use of alternative assessment strategies including performance-based assessments, peer reviews, and student reflections are the norm.

**Intensity Level 5**

At a CIP Intensity Level 5, the participant's instructional practices tend to lean more toward a learner-based approach. The essential content embedded in the standards emerges based on students "need to know" as they attempt to research and solve issues of importance to
them using critical thinking and problem-solving skills. The types of learning activities and teaching strategies used in the learning environment are diversified and driven by student questions. Both students and teachers are involved in devising appropriate assessment instruments (e.g., performance-based, journals, peer reviews, self-reflections) by which student performance will be assessed. However, the use of teacher-directed activities (e.g., lectures, presentations, teacher-directed projects) may surface based on the nature of the content being addressed and at the desired level of student cognition.

**Intensity Level 6**

Similar to a CIP Intensity Level 7, the participant at a CIP Intensity Level 6 supports instructional practices consistent with a learner-based approach, but not at the same level of intensity or commitment. The essential content embedded in the standards emerges based on students "need to know" as they attempt to research and solve issues of importance to them using critical thinking and problem-solving skills. The types of learning activities and teaching strategies used in the learning environment are diversified and driven by student questions. Students, teacher/facilitators, and occasionally parents are all involved in devising appropriate assessment instruments (e.g., performance-based, journals, peer reviews, self-reflections) by which student performance will be assessed.

**Intensity Level 7**

At a CIP Intensity Level 7, the participant's current instructional practices align exclusively with a learner-based approach to teaching and learning. The essential content embedded in the standards emerges based on students "need to know" as they attempt to research and solve issues of importance to them using critical thinking and problem-solving skills. The types of learning activities and teaching strategies used in the learning environment are
diversified and driven by student questions. Students, teacher/facilitators, and occasionally parents are all involved in devising appropriate assessment instruments (e.g., performance-based, journals, peer reviews, self-reflections) by which student performance will be assessed.

(Learning Quest, 2011)
Appendix G

LoTi Digital Age Calculation Key

DETAILS to LoTi Calculation Key
After determining the variables using the DETAILS Quick Scoring Device, apply the following rules in order to determine a participant's final LoTi Score.

If Computer Access? is FALSE, LoTi Score = 0
If Highest Raw LoTi Score is < 6, LoTi Score = 0
If Highest Raw LoTi Score is < 10, LoTi Score = 1
If Highest Raw LoTi Score is < 15, LoTi Score = 2
If Highest Level 5/6 has Raw LoTi Score ≥ 33 and PCU is ≥ 30 and CIP is ≥ 30 and Highest Level 0 is ≤ 15, LoTi Score = 6
If Highest Level 5/6 has Raw LoTi Score ≥ 25 and PCU is ≥ 25 and CIP is ≥ 25 and Highest Level 0 is ≤ 15, LoTi Score = 5
If Highest Level 5/6 has Raw LoTi Score ≥ 25 and (PCU is ≥ 20 and PCU is < 25) and (CIP is ≥ 20 and CIP is < 25) and Highest Level 0 is ≤ 15, LoTi Score = 4b
If Highest Level 4a/4b has Raw LoTi Score ≥ 25 and PCU is ≥ 20 and CIP is ≥ 25 and Highest Level 0 is ≤ 15, LoTi Score = 4b
If Highest Level 4a/4b has Raw LoTi Score ≥ 25 and (PCU is ≥ 15 and PCU is < 20) and (CIP is ≥ 20 and CIP is < 25) and Highest Level 0 is ≤ 20, LoTi Score = 4a
If Highest Level 4a/4b has Raw LoTi Score ≥ 20 and PCU is ≥ 15 and CIP is ≥ 20 and Highest Level 0 is ≤ 20, LoTi Score = 4a
If Highest Level 4a/4b has Raw LoTi Score ≥ 20 and PCU is ≥ 15 and (CIP is ≥ 15 and CIP is < 20), LoTi Score = 3
If Highest Level 3 has Raw LoTi Score ≥ 15 and PCU is ≥ 15, LoTi Score = 3
If Highest Level 3 has Raw LoTi Score ≥ 15 and PCU is < 15 and Highest Level 3 Raw Score > Highest Level 0 Raw Score, LoTi Score = 2
If Highest Level 1/2 has Raw LoTi Score ≥ 15 and PCU is ≥ 10 and Highest Level 1/2 Raw Score > Highest Level 0 Raw Score, LoTi Score = 2
If Highest Level 1/2 has Raw LoTi Score ≥ 15 and Highest Level 1/2 Raw Score > Highest Level 0 Raw Score, LoTi Score = 1
If Highest Level 0 has Raw LoTi Score ≥ 15, LoTi Score = 0
LoTi Digital-Age Quick Scoring Device to obtain a LoTi Score

Use this Quick Scoring Device to calculate the "High Score" and "High Level" numbers for scoring, then use the calculated values on the LoTi Digital-Age Survey Calculation Key to obtain a final LoTi Score from the 37-question LoTi Digital-Age Survey.

<table>
<thead>
<tr>
<th>DCR</th>
<th>Level 1/2</th>
<th>Level 3</th>
<th>Level 4a/4b</th>
<th>Level 5/6</th>
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<th>CIP</th>
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<tbody>
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<td>Q41</td>
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<tr>
<td>Q48</td>
<td>Q38</td>
<td>Q40</td>
<td>Q43</td>
<td>Q47</td>
<td>Q49</td>
<td>Q50</td>
</tr>
</tbody>
</table>

**STEP 1: Add for Raw Scores**

|   | 6 | 5 | 6 | 5 | 5 |

**STEP 2: Divide to find Averages**

<table>
<thead>
<tr>
<th>High Score</th>
<th>1/6</th>
<th>1/5</th>
<th>1/6</th>
<th>1/5</th>
<th>1/5</th>
</tr>
</thead>
</table>

**STEP 3: Record the largest High Score that was calculated (e.g., 6.2) = **

**High Score**

**STEP 4: Record the High Level that corresponds with the High Score from STEP 3 (e.g., 2) = **

**High Level**
Appendix I

Permission to Use of LoTi Framework

May 14th, 2012

Permission for Use of the LoTi Framework

To: Duquesne University
   Dissertation Review Boards

Please accept this letter as notification that Ahmet Akcay is hereby granted permission to utilize the LoTi Framework and corresponding Digital-Age Survey to collect data for his doctoral dissertation study. Ahmet is permitted to use the Digital-Age Survey and the LoTi Framework for purposes of the study only. In addition, Ahmet has permission to review all available LoTi Digital-Age results on the individuals taking place in his study.

The guidelines for using LoTi Connection copyrighted material as part of this dissertation study are as follows:

1. Permission to reprint the LoTi Framework is granted provided that the content remains unchanged and that attribution is given to LoTi Connection.
2. Permission to reprint selected results including graphs and tables in the Appendices of the study is granted provided that the content remains unchanged and that attribution is given to LoTi Connection.
3. Permission to reprint selected questions from the Digital-Age Survey in the Appendices of the study is granted provided that the content remains unchanged and that attribution is given to LoTi Connection.
4. LoTi Connection holds the right to restrict usage of any intellectual property if LoTi Connection finds that the content is being used in an inappropriate manner.

Sincerely,

Dennee Saunders
Assistant Executive Director

Date 05/14/2012
Appendix J
National Educational Technology Standards (NETS•T)
and Performance Indicators for Teachers

The ISTE
National Educational Technology Standards (NETS•T)
and Performance Indicators for Teachers

Effective teachers model and apply the National Educational Technology Standards for Students (NETS•S) as they design, implement, and assess learning experiences to engage students and improve learning; enrich professional practice; and provide positive models for students, colleagues, and the community. All teachers should meet the following standards and performance indicators. Teachers:

1. Facilitate and Inspire Student Learning and Creativity
   Teachers use their knowledge of subject matter, teaching and learning, and technology to facilitate experiences that advance student learning, creativity, and innovation in both face-to-face and virtual environments. Teachers:
   a. promote, support, and model creative and innovative thinking and invention
   b. engage students in exploring real-world issues and solving authentic problems using digital tools and resources
   c. promote student reflection using collaborative tools to reveal and clarify students' conceptual understanding and thinking, planning, and creative processes
   d. model collaborative knowledge construction by engaging in learning with students, colleagues, and others in face-to-face and virtual environments

2. Design and Develop Digital-Age Learning Experiences and Assessments
   Teachers design, develop, and evaluate authentic learning experiences and assessments incorporating contemporary tools and resources to maximize content learning in context and to develop the knowledge, skills, and attitudes identified in the NETS•S. Teachers:
   a. design or adapt relevant learning experiences that incorporate digital tools and resources to promote student learning and creativity
   b. develop technology-enriched learning environments that enable all students to pursue their individual curiosities and become active participants in setting their own educational goals, managing their own learning, and assessing their own progress
   c. customize and personalize learning activities to address students' diverse learning styles, working strategies, and abilities using digital tools and resources
   d. provide students with multiple and varied formative and summative assessments aligned with content and technology standards and use resulting data to inform learning and teaching

3. Model Digital-Age Work and Learning
   Teachers exhibit knowledge, skills, and work processes representative of an innovative professional in a global and digital society. Teachers:
   a. demonstrate fluency in technology systems and the transfer of current knowledge to new technologies and situations
   b. collaborate with students, peers, parents, and community members using digital tools and resources to support student success and innovation
   c. communicate relevant information and ideas effectively to students, parents, and peers using a variety of digital-age media and formats
   d. model and facilitate effective use of current and emerging digital tools to locate, analyze, evaluate, and use information resources to support research and learning

4. Promote and Model Digital Citizenship and Responsibility
   Teachers understand local and global societal issues and responsibilities in an evolving digital culture and exhibit legal and ethical behavior in their professional practices. Teachers:
   a. advocate, model, and teach safe, legal, and ethical use of digital information and technology, including respect for copyright, intellectual property, and the appropriate documentation of sources
   b. address the diverse needs of all learners by using learner-centered strategies and providing equitable access to appropriate digital tools and resources
   c. promote and model digital etiquette and responsible social interactions related to the use of technology and information
   d. develop and model cultural understanding and global awareness by engaging with colleagues and students of other cultures using digital-age communication and collaboration tools

5. Engage in Professional Growth and Leadership
   Teachers continuously improve their professional practice, model lifelong learning, and exhibit leadership in their school and professional community by promoting and demonstrating the effective use of digital tools and resources. Teachers:
   a. participate in local and global learning communities to explore creative applications of technology to improve student learning
   b. exhibit leadership by demonstrating a vision of technology infusion, participating in shared decision making and community building, and developing the leadership and technology skills of others
   c. evaluate and reflect on current research and professional practice on a regular basis to make effective use of existing and emerging digital tools and resources in support of student learning
   d. contribute to the effectiveness, vitality, and self-renewal of the teaching profession and of their school and community

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Appendix K

Approved Consent Form

Duquesne University IRB
Protocol #: 2014-04-6
Approval Date: 5-6-2014
Expiration Date: 5-6-2015

DUQUESNE UNIVERSITY
600 FORBES AVENUE ♦ PITTSBURGH, PA 15282

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

TITLE: Pre-Service Mathematics Teachers' Implementation of Technology

PRIMARY INVESTIGATOR: Ahmet O. Akcay
G9 Canacin Hall
600 Forbes Ave.
Pittsburgh, PA, 15282
Phone: 210-473-5142
akcay@duq.edu

CO-INVESTIGATOR: Melissa Boston, Associate Professor
Mathematics Education, Duquesne University
G14 Canacin Hall
600 Forbes Ave.
Pittsburgh, PA, 15282
bostonm@duq.edu

PURPOSE: The purpose of this study is to examine how pre-service teachers are using technology to teach mathematics. The study will identify what technological tools pre-service teachers are using and the mathematical quality of instructional activities created or used during the methods course and student teaching. For this study, you will be asked to: 1) complete the "Levels of Technology Implementation" survey; 2) to provide permission for the researcher to use your "Technology Assignment" from the mathematics pedagogy course as data in this study; and 3) to provide permission for the researcher to use materials from your Student Teaching Showcase portfolio (e.g., copies of technology activities used while student teaching, and samples of students' work from these activities) as data for this study. The survey will be administered online (http://www.k12math.org/) and should be taken approximately 20 minutes of your time. These are the only request that will be made of you.

RISKS AND BENEFITS: There are minimal foreseeable risks associated with this study, no greater than everyday life. There are no direct benefits to you for participating in this research however this study could help inform how PSTs at Duquesne University are prepared to use technology to teach mathematics.

COMPENSATION: There will be no monetary compensation to you, and participation will not cost you anything either.

CONFIDENTIALITY: To protect confidentiality of research subjects, all participants in the study will be assigned a pseudonym and a code by the principle investigator. All data collected from that participant will be identified by that pseudonym and/or code. All information that link pseudonym and actual persons will be kept in a locked file and only Dr. Melissa Boston will have access to it. Dr. Boston will have overall responsibility for the control of this area. Data will be kept for five years after the completion of the study.

It is possible that information gathered in research will become part of a published product. In written description and reports of what is learned from the study, the
instructors/researchers will remove information that identifies individuals. Any information about you obtained from this research will be kept as confidential (private) as possible. You will not be identified by name in any publication of research results. Research records will be kept for a minimum of five years past study completion.

Your course instructor will not know whether or not you have chosen to participate in this study until after grades are issued. Your decision to participate or not will not impact your grade in the mathematics method courses or student teaching.

No identifying information pertaining to students in the pre-service teachers’ classroom will be collected. All student work will be “blinded” such that researchers have no access to identifying information about students. K-12 students are not considered as subjects in this study.

RIGHT TO WITHDRAW: Participation in this study is entirely voluntary. Refusal of participation will not affect the participants in any way. Participants are free to withdraw from the study at any time by closing out the online survey page. Incomplete responses will be excluded from the data set during data analysis. Due to the anonymous nature of the responses to the survey, completed surveys cannot be withdrawn.

SUMMARY OF RESULTS: A summary of the results of this research will be supplied to you, at no cost, upon your request.

VOLUNTARY CONSENT: I have read the above statements and understand what is being requested of me. I also understand that my participation is voluntary and that I am free to withdraw my consent at any time, for any reason. On these terms, I certify that I am willing to participate in this research project.

I understand that should I have any further questions about my participation in this study, I may call Ahmet Akcay at 210-473-5143. I may also call the chair of the Duquesne University Institutional Review Board, Dr. Linda Goodfellow at 412-396-6326.

I have read the above statements and understand that my participation is voluntary. On these terms, I certify that I am willing to participate in this research project.

Participant’s Signature __________________________  Date __________

Researcher’s Signature __________________________  Date __________
CONSENT TO PARTICIPATE IN A RESEARCH STUDY

TITLE: Pre-Service Mathematics Teachers’ Implementation of Technology

PRIMARY INVESTIGATOR: Ahmet O. Akcay
G9 Canевin Hall
600 Forbes Ave.
Pittsburgh, PA, 15282
Phone: 212-473-5142
akcaya@duq.edu

CO-INVESTIGATOR: Melissa Boston, Associate Professor
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CONFIDENTIALITY: To protect confidentiality of research subjects, all participants in the study will be assigned a pseudonym and a code by the principle investigator. All data collected from that participant will be identified by that pseudonym and/or code. All information that link pseudonym and actual persons will be kept in a locked file and only Dr. Melissa Boston will have access to it. Dr. Boston will have overall responsibility for the control of this area. Data will be kept for five years after the completion of the study.

It is possible that information gathered in research will become part of a published product. In written description and reports of what is learned from the study, the
instructors/researchers will remove information that identifies individuals. Any information about you obtained from this research will be kept as confidential (private) as possible. You will not be identified by name in any publication of research results. Research records will be kept for a minimum of five years past study completion.

Your course instructor will not know whether or not you have chosen to participate in this study until after grades are issued. Your decision to participate or not will not impact your grade in the mathematics method courses or student teaching.

No identifying information pertaining to students in the pre-service teachers' classroom will be collected. All student work will be “blinded” such that researchers have no access to identifying information about students. K-12 students are not considered as subjects in this study.

**RIGHT TO WITHDRAW:** Participation in this study is entirely voluntary. Refusal of participation will not affect the participants in any way. Participants are free to withdraw from the study at any time by closing out the online survey page. Incomplete responses will be excluded from the data set during data analysis. Due to the anonymous nature of the responses to the survey, completed surveys cannot be withdrawn.

**SUMMARY OF RESULTS:** A summary of the results of this research will be supplied to you, at no cost, upon your request.

**VOLUNTARY CONSENT:** I have read the above statements and understand what is being requested of me. I also understand that my participation is voluntary and that I am free to withdraw my consent at any time, for any reason. On these terms, I certify that I am willing to participate in this research project.

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I have read the above statements and understand that my participation is voluntary. On these terms, I certify that I am willing to participate in this research project.

Participant’s Signature ___________________________ Date ___________________________
Appendix L

LOTI Digital Age Survey

LoTi Digital-Age Survey for Teachers

©2013 LoTi

Version 2013
Using the LoTi Digital-Age Survey for professional development planning is part of an ongoing nationwide effort to sharpen educator skill sets as defined by the Partnership for 21st Century Skills. Individual information will remain anonymous, while the aggregate information will provide various comparisons for your school, school district, regional service agency, and/or state. Please fill out as much of the information as possible.

The LoTi Digital-Age Survey takes about 20-25 minutes to complete. The purpose of this questionnaire is to determine your current professional development priorities related to technology and instruction based on your current position (i.e., pre-service teacher, in-service teacher, building administrator, instructional specialist, media specialist, higher education faculty).

Completing the questionnaire will enable your educational institution to make better choices regarding staff development and future technology purchases. The questionnaire statements were developed from typical responses of educators who ranged from non-users to sophisticated users of technology in the classroom. Survey statements will represent different uses of technology that you currently experience or support, in varying degrees of frequency, and should be recorded appropriately on the scale.

Please respond to the statements in terms of your present uses or support of technology in the classroom. Use the scale to determine your response based on how frequently you experience the activities described in the statement.

**Instructional Environment**
How often are your students involved in standards-based learning experiences during the instructional day?

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<td>0</td>
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<td>1</td>
<td>At least once a year</td>
</tr>
<tr>
<td>2</td>
<td>At least once a month</td>
<td>3</td>
<td>At least once a week</td>
</tr>
<tr>
<td>4</td>
<td>At least once a day</td>
<td>5</td>
<td>Multiple times each day</td>
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**Teacher Computer Use (TCU):**
How often are you (the teacher) using digital tools and resources during the instructional day?

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<td>1</td>
<td>At least once a year</td>
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<tr>
<td>2</td>
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<td>3</td>
<td>At least once a week</td>
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<tr>
<td>4</td>
<td>At least once a day</td>
<td>5</td>
<td>Multiple times each day</td>
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</tbody>
</table>

**Student Computer Use (SCU):**
How often are your students using digital tools and resources during the instructional day?

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<tr>
<td>0</td>
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<td>1</td>
<td>At least once a year</td>
</tr>
<tr>
<td>2</td>
<td>At least once a month</td>
<td>3</td>
<td>At least once a week</td>
</tr>
<tr>
<td>4</td>
<td>At least once a day</td>
<td>5</td>
<td>Multiple times each day</td>
</tr>
</tbody>
</table>
LoTi Digital-Age Survey for Teachers

Q1: I engage students in learning activities that require them to analyze information, think creatively, make predictions, and/or draw conclusions using the digital tools and resources (e.g., Inspiration/Kidspiration, Excel, InspireData) available in my classroom.

Q4: Students in my classroom use the digital tools and resources to create web-based (e.g., web posters, student blogs or wikis, basic webpages) or multimedia presentations (e.g., PowerPoint) that showcase digitally their research (i.e., information gathering) on topics that I assign more than for other educational uses.

Q5: I assign web-based projects (e.g., web collaborations, WebQuests) to my students that emphasize complex thinking strategies (e.g., problem-solving, decision-making, experimental inquiry) aligned to the content standards.

Q6: I provide multiple and varied formative and summative assessment opportunities that encourage students to "showcase" their content understanding in nontraditional ways.

Q8: I use the digital tools and resources in my classroom to promote student creativity and innovative thinking (e.g., thinking outside the box, exploring multiple solutions).

Q10: My students identify important real world issues or problems (e.g., environmental pollution, elections, health awareness), then use collaborative tools and human resources beyond the school building (e.g., partnerships with business professionals, community groups) to solve them.

Q12: I promote, monitor, and model the ethical use of digital information and technology in my classroom (e.g., appropriate citing of resources, respecting copyright permissions).

Q13: I use different digital media and formats (e.g., blogs, online newsletters, online lesson plans, podcasting, digital documents) to communicate information effectively to students, parents, and peers.

Q14: My students propose innovative ways to use our school's advanced digital tools (e.g., digital media authoring tools, graphics programs, probeware with GPS systems) and resources (e.g., publishing software, media production software, advanced web design software) to address challenges/issues affecting their local and global communities.

Q15: I model and facilitate the effective use of current and emerging digital tools and resources (e.g., streaming media, wikis, podcasting) to support teaching and learning in my classroom.

Q16: Our classroom’s digital tools and resources are used exclusively for classroom management and professional communication (e.g., accessing the Internet, communicating with colleagues or parents, grading student work, and/or planning instructional activities).

Q17: The digital tools and resources in my classroom are used by me during the instructional day and not by my students.

Q18: I use different technology systems unique to my grade level or content area (e.g., online courseware, Moodle, WAN/LAN, interactive online curriculum tools) to support student success and innovation in class.

Q19: I employ learner-centered strategies (e.g., communities of inquiry, learning stations/centers) to address the diverse needs of all students using developmentally-appropriate digital tools and resources.

Q20: Students’ use of information and inquiry skills to solve problems of personal relevance influences the types of instructional materials used in my classroom.

Q21: My students participate in collaborative projects (e.g., Jason Project, Global/SchoolNet) involving face-to-face and/or virtual environments with students of other cultures that address current problems, issues, and/or themes.

Q22: My students use the available digital tools and resources for (1) collaboration with others, (2) publishing, (3) communication, and (4) research to solve issues and problems of personal interest that address specific content standards.

Q23: I model for my students the safe and legal use of digital tools and resources while I am delivering content and/or reinforcing their understanding of pertinent concepts using multimedia resources (e.g., PowerPoint, Keynote), web-based tools (e.g., Google Presentations), or an interactive whiteboard.
Q25: My students model the “correct and careful” (e.g., ethical usage, proper digital etiquette, protecting their personal information) use of digital resources and are aware of the consequences regarding their misuse.

Q26: I participate in local and global learning communities to explore creative applications of technology toward improving student learning.

Q27: I offer students learning activities that emphasize the use of digital tools and resources to solve "real-world" problems or issues.

Q30: I prefer using standards-based instructional units and related student learning experiences recommended by colleagues that emphasize innovative thinking, student use of digital tools and resources, and student relevancy to the real world.

Q31: I seek outside help with designing student-centered performance assessments using the available digital tools and resources that involve students transferring what they have learned to a real world context.

Q32: I rely heavily on my students' questions and previous experiences when designing learning activities that address the content that I teach.

Q36: My students use the classroom digital tools and resources to engage in relevant, challenging, self-directed learning experiences that address the content standards.

Q37: I design and/or implement web-based projects (e.g., WebQuests, web collaborations) in my classroom that emphasize the higher levels of student cognition (e.g., analyzing, evaluating, creating).

Q38: My students use the digital tools and resources in my classroom primarily to increase their content understanding (e.g., digital flipcharts, simulations) or to improve their basic math and literacy skills (e.g., online tutorials, content-specific software).

Q40: My students use digital tools and resources for research purposes (e.g., data collection, online questionnaires, Internet research) that require them to investigate an issue/problem, take a position, make decisions, and/or seek out a solution.

Q41: My students collaborate with me in setting both group and individual academic goals that provide opportunities for them to direct their own learning aligned to the content standards.

Q42: I promote global awareness in my classroom by providing students with digital opportunities to collaborate with others of various cultures.

Q43: My students apply their classroom content learning to real-world problems within the local or global community using the digital tools and resources at our disposal.

Q45: My students and I use the digital tools and resources (e.g., interactive whiteboard, digital student response system, online tutorials) primarily to supplement the curriculum and reinforce specific content standards.

Q46: Problem-based learning occurs in my classroom because it allows students to use the classroom digital tools and resources for higher-order thinking (e.g., analyzing, evaluating, creating) and personal inquiry.

Q47: My students use all forms of the most advanced digital tools (e.g., digital media authoring tools, graphics programs, probeware with GPS systems, handheld devices) and resources (e.g., publishing software, media production software, advanced web design software) to pursue collaborative problem-solving opportunities surrounding issues of personal and/or social importance.

Q48: I advocate for the use of different assistive technologies on my campus that are available to meet the diverse needs of special needs students.

Q49: I promote the effective use of digital tools and resources on my campus and within my professional community and actively develop the technology skills of others.

Q50: I consider how my students will apply what they have learned in class to the world they live when planning instruction and assessment strategies.
Appendix M

Technology Assignment Directions and Rubric

TMSM Technology Assignment

Technology Plan Due: ________________

Create an activity for each of the following instructional technology tools to incorporate into your unit plan to enhance students’ learning of the mathematical concepts:

- SmartBoard
- Graphing Calculator
- Internet resource

In the Unit plan, write up each technology activity as follows:

1) Describe each activity and your use technology. Provide copies of handouts, slides, websites, etc.

2) For each activity, describe (1-2 paragraphs) how your use of technology:
   a. addresses important mathematical content and is connected to the math ideas in your unit
   b. supports students’ mathematical learning
   c. promotes active participation/learning from students
   d. provides appropriate level of user support, including verbal directions

Use of technology will be evaluated on the following criteria:

- Connection to the math ideas in the unit
- Technology was used to support students’ mathematical learning
- Student engagement with the technology
- Appropriate level of user support
## TMSM Technology Assignment Rubric

<table>
<thead>
<tr>
<th>Quality of Activities</th>
<th>SmartBoard</th>
<th>Graphing Calculator</th>
<th>Internet Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connection to the math ideas in the unit</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Technology was used to support Ss mathematical learning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student engagement with the technology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appropriate level of user support</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Description of activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provided handouts, slides, websites, etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Score levels:

0: Inadequate  
1: Adequate  
2: Exemplary

**Technology Write-Ups:** Total ___/10 each

1. addresses important mathematical content (2 pts) and is connected to the math ideas in your unit (2 pts)  
2. supports Ss mathematical learning (2 pts)  
3. promotes active participation/learning from students (2 pts)  
4. provides appropriate level of user support, including verbal directions (2 pts)
Appendix N

Independent T-test Results for Showcase Portfolio and Technology Activities Created by Secondary Level PSTs

<table>
<thead>
<tr>
<th>Group Statistics</th>
<th>Grade Level</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
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## Independent Samples Test

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<th>t-test for Equality of Means</th>
<th>95% Confidence Interval of the Difference</th>
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<td>Sig.</td>
<td>t</td>
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<td></td>
<td></td>
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<td>.140</td>
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<td>Equal variances</td>
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Appendix O

Result of Chi-Square Test for LoTi-Digital Age Survey and IQA Rubrics

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<th>Target</th>
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<tr>
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<td>33.3%</td>
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<tr>
<td>% of Total</td>
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<td>5.0%</td>
<td>20.0%</td>
<td>35.0%</td>
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<tr>
<td>High</td>
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<td>2</td>
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<td>13</td>
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<tr>
<td>% within PT</td>
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### Chi-Square Tests

<table>
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<tr>
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<th>Value</th>
<th>df</th>
<th>Asymptotic Significance (2-sided)</th>
</tr>
</thead>
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<tr>
<td>Pearson Chi-Square</td>
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<td>.964</td>
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<tr>
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<td>1</td>
<td>.809</td>
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<sup>a</sup> 5 cells (83.3%) have expected count less than 5. The minimum expected count is 1.05.

### Symmetric Measures

<table>
<thead>
<tr>
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<td>Cramer's V</td>
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<td></td>
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## Potential of the Task (PT) * PCU Score

### Crosstab

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<th>PCU Score</th>
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<th></th>
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<td>2</td>
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<td>7</td>
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<td>28.6%</td>
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### Chi-Square Tests

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a. 5 cells (83.3%) have expected count less than 5. The minimum expected count is 2.10.

### Symmetric Measures

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<tr>
<td>Cramer's V</td>
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<td>.982</td>
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### Potential of the Task (PT) * CIP Score

#### Crosstab

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<tr>
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<td><strong>Task</strong></td>
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<td></td>
</tr>
<tr>
<td><strong>Count</strong></td>
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<tr>
<td><strong>% within PT</strong></td>
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#### Chi-Square Tests

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<tr>
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a. 4 cells (66.7%) have expected count less than 5. The minimum expected count is .35.

#### Symmetric Measures

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## Described Implementation (DI) * LoTi Score

### Crosstab

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<tr>
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### Chi-Square Tests

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<tr>
<td>N of Valid Cases</td>
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<td></td>
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</tbody>
</table>

\(^a\) 5 cells (83.3%) have expected count less than 5. The minimum expected count is .30.

### Symmetric Measures

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<tr>
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**Chi-Square Tests**

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<tr>
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</thead>
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<sup>a</sup>. 3 cells (50.0%) have expected count less than 5. The minimum expected count is .60.

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### Described Implementation (DI) * CIP Score

#### Crosstab

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<th></th>
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#### Chi-Square Tests

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*a. 5 cells (83.3%) have expected count less than 5. The minimum expected count is .10.*

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<tr>
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<td>Nominal by Nominal Phi</td>
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## Expected Student Response (ESR) * LoTi Score

### Crosstab

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<tr>
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### Chi-Square Tests

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<tbody>
<tr>
<td>Pearson Chi-Square</td>
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<td>.036</td>
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a. 5 cells (83.3%) have expected count less than 5. The minimum expected count is .30.

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### Expected Student Response (ESR) * PCU Score

#### Crosstab

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### Expected Student Response (ESR) * CIP Score Crosstab

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