IMPLICATIONS FOR INTEGRATING THE INTERACTIVE WHITEBOARD AND PROFESSIONAL DEVELOPMENT TO EXPAND MATHEMATICS TEACHERS TPACK IN AN URBAN MIDDLE SCHOOL

A Dissertation

by

JAMAAL RASHAD YOUNG

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2011

Major Subject: Curriculum and Instruction

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ABSTRACT

Implications for Integrating the Interactive Whiteboard and Professional Development to Expand Mathematics Teachers TPACK in an Urban Middle School. (August 2011)

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The Federal Government is dedicated to improving student achievement through technology. This dedication is most apparent in the area of federal spending. One explanation for the lack of results in student achievement is that teachers need appropriate training to effectively teach with technology.

This study integrates the interactive whiteboard and professional development in order to develop middle school mathematics teachers' Technological Pedagogical Content knowledge (TPACK) in an urban school. Teacher TPACK is measured on a modified version of *Survey of Teacher Knowledge to Teach with Technology.* Student achievement is measured on the Texas Assessment of Knowledge and Skills (TAKS), a standardized mathematics assessment. Teachers in this study receive three weeks of professional development during their team planning periods to help them integrate the Interactive Whiteboard (IWB) into their mathematics instruction. Mean difference effect sizes are used to measure teacher gain in TPACK. Student achievement scores before and after the professional development are analyzed by Multi-way ANOVA after propensity scores are used to match participant students to a separate group of control students for comparison.

The results indicate that the professional development increased teacher TPACK and that student achievement is differentiated across ethnicities. Implications for the technology professional development design and IWB integration in urban settings are provided.

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INTRODUCTION

The integration of technology in the classroom is cited as an important component of student success in mathematics (National Council of Teachers of Mathematics, 2000). In response to the growing importance of technology in K-12 education, the federal government, as well as individual states, invested substantial amounts of money to increase student and teacher access to technology. As a result, over the past decade, schools have made considerable increases in their technology infrastructure, as well as the development of educational technology (Alavi & Leidner, 2001; Russell, Bebell, O'Dwyer, & O'Connor, 2003). The proliferation of educational technology in the United States has provided teachers with more electronic resources than ever before, but some teachers have not received sufficient training in the effective use of technology to enhance learning (Niess, 2005). A national survey of technology implementation in mathematics classrooms found that almost half of American students are in classrooms where teachers lack access to district or school provided professional development on the use of computers for mathematics instruction (Mitchell, Bakia, & Yang, 2007).

This dissertation follows the style of *Journal of Technology Education.*

Despite these investments, a report by the U.S. Department of Education states that the benefits of technology integration on student achievement remain unseen (Paige, 2005). One explanation for the lack of results on student achievement is that teachers need appropriate training to effectively teach with technology. Proper training requires administrative support for the integration of technology in the classroom. Educational policy and funding has made it tremendously advantageous for administrators to support technology integration.

Background

The Federal Government is dedicated to improving student achievement through technology. This dedication is most apparent in the area of federal spending. Funds were spent to addressed the following technology initiatives in the last decade: (a) school technology infrastructure, (b) pre-service teacher training, (c) providing on-going training and professional development for the educational workforce, and (d) eliminating inequitable access to technology (Lawless & Pellegrino, 2007). The Obama administration continued the previous administrations efforts to support technology integration in an effort to improve teacher training and student achievement.

The previous reauthorization of the Elementary and Secondary Education Act (ESEA), No Child Left Behind (NCLB), specifically stated that one of its purposes was "To enhance the ongoing professional development of teachers, principals, and administrators by providing constant access to training and updated research in teaching and learning through electronic means" (U.S. Department of Education, 2001, Purposes and Goals section, ¶ 5). According to NCLB, teachers needed training to effectively teach with technology. The current administration has continued these efforts by providing more funding and emphasis on educational technology.

The American Recovery and Reinvestment Act devoted 650 million dollars to education technology in an effort to continue improving teaching and learning. The current reauthorization of the ESEA hopes to provide guidelines and administrative support for the appropriation of these funds to improve the use of technology for instruction (U.S. Department of Education, 2010). One way in which this policy promotes the effective use of technology in the classroom is by giving funding priority to schools that use technology to address student-learning challenges (U.S. Department of Education). Although large sums of federal monies were spent to support technology integration, increasing access to technology will not change teaching and learning, only teachers can change teaching and learning.

The Use of Technology Is Not a Catalyst for Instructional Change

Technological tools are important components of present and future teaching, but these tools are not catalyst for instructional change. When technology is introduced to teachers other factors ultimately determine whether or not teachers accept the technology tool into their practice and make the appropriate changes in instruction. Although there exist a prior research base to support technology as a catalyst for instructional change (Roschelle, Pea, Hoadley, Gordin, & Means, & 2000; Sandholtz, Ringstaff, & Dwyer, 1999), a closer investigation reveals that contextual factors may be the mediating agent supporting these changes in instruction (Cuban, Kirkpatrick, & Beck, 2001; Windschitl & Sahl, 2002; Zhao, Pugh, Sheldon, & Byers, 2002). The effects of technology on instruction are dependent on several contextual factors as well as the user of the tool. Dexter, Anderson, and Becker (1999) found that teachers cited reflection on experience, classes taken, and the context or culture of the school as the major catalyst of instructional change when technology is introduced.

Much of the current debate on the impact of technology in the classroom attempts to isolate the technological tools as the sole catalyst for improved teaching and learning (Watson, 2001). Technology however, is not a catalyst for instructional change because technology is only a tool, much like a chalkboard or any of the other common classroom tools to support instruction. Because different technologies have different affordances and constraints, technology alone cannot be credited with improved teaching and learning. Affordances describe the opportunities or potential benefits provided by a tool, and are typically conveyed in a manner that the tool can be used for continued success (John & Sutherland, 2005; Webb, 2005), this idea was originally adapted by Norman (1998) to characterize the attributes of machines. While . Teachers must not only understand how to use the technology effectively in the classroom, but believe that the technology is viable in their classroom, because teacher use of technology is highly correlated with teacher instructional beliefs (Dexter, Anderson, & Becker, 1999; Ertmer, Addison, Lane, Ross, & Woods, 1999). The teacher is in control of the teaching and learning in the classroom, thus the teacher is the primary catalyst to any instructional change that takes place when technology is introduced. Further, teacher pedagogical beliefs are highly influential on teacher instructional practices with technology, thus bridging the gap between pedagogical practice, content, and technology is vital to instructional changes.

Bridging PCK and TPACK

The thoughtful and purposeful use of technology requires an understanding of how pedagogy, content, and technology enhance and constrain one another. Specifically how the user's technical competence in relation to the pedagogical affordances of the tool can enhance lesson delivery. Technology tools have different didactical functionalities that describe: (a) a set of characteristics of the tool, (b) a specific learning goal, and (c) a set of modalities for employing the tool in a specific learning process to achieve the specific goal (Cerulli, Pedemonte, & Robotti, 2006). It is important for teaching and student learning to understand the characteristics, modalities for use, and the specific learning goals of the tool. For example, if multiple representations of functions were the learning goal for an algebra lesson, then an appropriate technology tool would be the graphing calculator. The graphing calculator is a technological tool that is commonplace in many secondary classrooms and the graphing calculator has several characteristics or affordances suitable for classroom use.

In this instance, the goal is to teach multiple representations of functions, thus the characteristics of the graphing calculator that are appropriate include the ability of the tool to show functions in symbolic, tabular, and graphic form. The modalities of use in this case are somewhat debatable, but they hinge upon the teachers and students prior experience with graphing calculators, as well as specific content and pedagogical factors. At a very basic level, the teacher could use the device to input a symbolic representation of a function, then show the students the table or graph. This process could be executed in the reverse order, but the technical difficulty, as well as instructional implications, is again dependent on the classroom setting. Thus, the important issue for the integration of technology is not the availability of sophisticated educational technologies, but the ways these devices afford educators the ability to create dynamic learning environments that aid students in extracting meaning out of complexity (Dede, 2000). In order to take full advantage of these affordances, technology must be used thoughtfully and purposefully (McCoog, 2007).

Technological Pedagogical Content Knowledge (TPACK) is a viable educational framework for effective teaching with technology (Mishra & Koehler, 2006). Because effective teaching with technology requires educators to understand the affordances and constraints of technology on educational practice, TPACK is an appropriate framework for educators to better ascertain the affordances and constraints of technology in the classroom (Koehler & Mishra, 2008). TPACK is an educational framework for effective teaching with technology that emphasizes the intersection between technological knowledge and pedagogical content knowledge (PCK).

Shulman (1986) championed the need for educators to understand the intersection between content and pedagogy. According to Shulman content knowledge was the amount and organization of knowledge in the mind of the teacher, while pedagogical knowledge was the extension of content knowledge to include subject matter knowledge for teaching (p. 9). While pedagogy "is the knowledge of generic principles of classroom organization and management and the like that has quite appropriately been the focus of study in most recent research on teaching" (p.14). The intersection of knowledge and pedagogical knowledge is PCK. This type of knowledge includes: (a) the most regularly taught topics in one's subject area, (b) the most used representations of these ideas, as well as, (c) the most powerful analogies, illustrations, examples, explanations, and demonstrations in the world (p.9). Shulman further asserts that PCK includes an understanding of what makes the learning of specific "content easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons" (p. 9). Thus it is important that teachers understand the complexities of PCK before that can bridge the gap between PCK and TPACK.

TPACK extended the PCK framework to include technological knowledge. TPACK is an educational framework that encompasses many uses of technology in the classroom, however, it is not a universal knowledge or skill set that can be applied hap hazardously. If teacher are to teach effectively with the IWB they must first have strong mathematics PCK, in order to bridge the gap between these two types of knowledge. Strong PCK allows the teacher to investigate how the digital tool can enhance their ability to ability to implement their PCK.

The Interactive Whiteboard

The Interactive whiteboard (IWB) is a large touch screen device that is connected to a digital projector and computer. The IWB allows the user to create lesson materials in advance or instantaneously during a lesson, quickly retrieve the materials for display, and manipulate the materials on the display for the entire class (Kennewell, Tanner, Jones, & Beaucamp, 2008). The IWB is an information communication technology (ICT) that offers numerous affordances for increased student engagement and subsequent achievement when compared to the dry erase board. Although dry erase boards and IWB share the same basic function, the affordances and constraints are different. Some shared affordances are that both devices allow educators to present data on a large visible area, the use of multiple colors to accent information, and with the addition of a projector educators can annotate documents. Despite some shared affordances, IWB's have the additional ability to deliver interactive digital learning content and integrate virtual content, as well as ICT activities. Because appropriate use of the IWB involves maximizing its affordances, the IWB alone does not ensure academic progress (Glover, Miller, Averis, & Door, 2007).

Factors Associated with Effective Professional Development

The purpose of professional development is to yield positive effects in teaching and learning. Therefore, if professional development is effective it should influence teaching and learning positively. A reasonable assumption is that certain factors or "best practices" exist in the professional development literature. Accordingly, it is relatively easy to search the professional development literature and locate dozens of studies claiming to identify the factors necessary for professional development to be effective (Guskey, 2003a; Guskey, 2003b). However, empirical evidence that isolates particular factors as contributors to consistent effectiveness is scarce (Wayne, Yoon, Zhu, Cronen, & Garet, 2008). Further, scientifically sound evidence on the relationship between professional development and student achievement is particularly modest (Guskey, 2009; Guskey & Yoon, 2009). For example, the National Mathematics Advisory Panel (2008) concluded that the majority of mathematics professional development studies lacked sufficient rigor in terms of the design process utilized. The panel suggests that in order to warrant sound causal inferences studies should be true experiments with an experimental and control group rather than a one-group prettest/posttest design, which is the norm in professional development studies. Despite some debate on the ability to derive causal inferences from most professional development literature, there is some consistency in the factors associated with effective professional development.

Five factors are consistently cited as critical to increasing teacher knowledge and skills, while fostering increases in student achievement (Desimone, 2009; Hawley & Valli, 1999; Wilson & Berne, 1999). These factors are: (a) content focus, (b) duration, (c) active learning , (d) coherence, and (c) collective participation.

Content

Professional development is designed to foster changes in teacher knowledge and practice, which hinges upon the classroom content that teachers are charged to transmit to their students. Therefore, it is imperative that professional development focus on the specific content needs of participants. The importance of a content focus in professional development is supported by a plethora of studies that implemented several different experimental designs in different educational context, with similar outcomes (Banilower, Heck, & Wess, 2005; Cohen & Hill, 2001; Desimone, Porter, Garet, Yoon, Birman, 2002; Smith et al., 2007). All of these studies supported the assertion that content focus is a necessary element of effective professional development. Thus, it seems as though focusing on content is important in any education context because content can serve as a great conduit for the primary goals of professional development activities.

Duration

Time is an enduring element of effective professional development that is recognized as extremely necessary to sustain changes in knowledge and practice. However, simply providing more time does not yield any benefits unless the time is used wisely. According to Guskey and Yoon (2009) the duration of a professional development program is only relevant if that time is well organized, carefully structured, purposefully directed, and focused on content or pedagogy or both. Along with the initial duration of the professional development, time spent providing feedback and follow-up is also important to support teachers begin to implement changes in their practice.

Active Learning

There is relatively little consensus on the most appropriate delivery method of professional development. However, there is adequate research to support opportunities for active learning as a key feature of effective professional development. Passive lecture based professional development sessions typically do not invoke the same amount of authentic support for the goals of the session as other activities. Active learning in professional development can include many activities such as, observing expert teaching, being observed with interactive feedback, reviewing student work, or participating in a discussion group (Banilower & Shimkus, 2004; Borko, 2004). These activities involve the participants in the professional development in meaningful ways that leave then more vested in the learning outcomes. The final two components work in conjunction to support professional development activities. This is supported by the results of the Teaching Commission (2004) report *Teaching at Risk: A Call to Action.* In their report the commission suggest that professional development should emphasize coherence as well as collective participation.

Coherence

Schools rarely implement initiatives one at a time; instead it is normal for a school to have multiple improvement initiatives taking place simultaneously (Guskey, 2009). Coherence is therefore necessary due to the nature of schools and the manner in which they implement procedural, instructional, and policy changes. In order for professional development to be effective it is important that there is coherence between the information presented in the professional development and the institutional policies of the school. This type of consistency should transcend the school and district to include state and national reforms (Firestone, Mangin, Martinez, Polovsky, 2005; Penuel et al., 2007), because teachers will be reluctant to implement any programs or activities that are contrary to what is already in place. Thus, coherence is a necessary factor in effective professional development.

Collective Participation

The participation of teachers from the same school, grade, or department is another crucial element of effective professional development referred to as collective participation (Desimone, 2009). Collective participation allows educators to collaborate during professional development with others with like interest and a collective investment in the success of a particular district, school, or grade. This benefits of collective participation help to unite schools on common interest and goals to work to improve as a whole rather as groups of individuals. Garet, Porter, Desimone, Birman, and Yoon (2000) in their work *What Makes Professional Development Effective? Results from a National Sample of Teachers,* categorized the aforementioned factors into core features and structural components of effective professional development.

According to Garet et al. core features such as: (a) focus on content, (b) opportunities for active learning, and (c) coherence with other learning activities are the primary catalyst to the teacher learning effects seen in structural components. These structural components are (a) the form of the activity, (b) collective participation of teachers from the same school, grade, and subject area, and (c) the duration of the activity. According to Garet et al. the core features drive the influences on the structural components. Likewise, Guskey (2009) suggests that a collection of core elements that must be adapted to unique characteristics and contexts of a particular school may describe effective professional development better than a unique list of "best practices". Therefore, professional development leaders should adopt the core features as described by Garet el al. that support the structural components described by Garet et al. best suited for the characteristics and contextual issues present in each professional development setting.

Statement of the Problem

The use of the IWB may be the most significant change in the classroom-learning environment in the past decade (Higgins, Beaucamp, & Miller, 2007). The IWB entered the classroom in the early 90's, and has replaced the traditional chalk/whiteboard in many classrooms. The IWB is a technology tool that was designed specifically for educational use, and has become a focal point of many classroom interactions. However, many teachers have not received adequate training to utilize the many affordances of these tools. Miller and Glover (2007) found that the introduction of IWB technology without sufficient training on the technology, and how to teach mathematics with the technology could inhibit the benefits of the IWB in the classroom.

Training for the IWB is necessary because the IWB should not be utilized in the same manner as the traditional chalk or whiteboard, but rather the power of the IWB is in the ability to exploit the affordances for interactivity. Even relatively experiences IWB users may not develop the ability to fully exploit the affordances of the IWB due to the restrains of curriculum, time, and the amount of pre-planning necessary to use the IWB (Hennessy, Deaney, Ruthven, and Winterbottom, 2007). In order for teachers to take full advantage of the pedagogical affordances of the IWB, teachers must developed a dynamic understanding of the features of the IWB, and learn to interact fluidly with the IWB during instruction (Glover & Miller, 2002; Warren, 2003). According to Higgins, Beauchamp, and Miller (2007) the research literature is void of examples of how the IWB can promote instructional and pedagogical changes that yield changes in student learning. The goal of this study was to address the lack of training in the use of the IWB for teaching mathematics as a mechanism to increase student achievement in mathematics. This was achieved though the design, implementation, and evaluation of professional development for teaching mathematics with the IWB.

Purpose of the Study

The purpose of this study is to examine the effects of a professional development for using the IWB on teacher TPACK and student achievement. Although intensive professional development can change teacher knowledge and practice (Borko, 2004), the focus of this study was to increase teacher TPACK and student achievement, not practice. To this end, teachers involved in this professional development will gain a better self-efficacy about their: (a) mathematics content knowledge, (b) mathematics pedagogical knowledge, (c) IWB technical knowledge, and (d) ability to combine all of the previously mentioned types of knowledge to maximize the affordances of the IWB to teach mathematics effectively. This new found knowledge will in turn lead to indirect improvements in student achievement, measured my a standardized testing instrument.

Rationale

Technology can be utilized to transform instruction and student experiences when utilized in conjunction with a strong foundation in content and pedagogy, yet technology integration has yet to transform educational practice. One explanation is that technology integration has numerous barriers to success. The potential barriers, though plentiful, can be categorized into essentially four categories. According to Brinkerhoff (2006) the impediments to technology integration can be categorized by the following: (1) lack resources, (2) insufficient institutional and administrative support, (3) lack of training and professional development, and (4) attitudinal or personality factors toward technology. Teacher knowledge is the first step in developing the skills necessary to foster changes in classroom practice. In order for teachers to begin to integrate technology into their classroom in meaningful ways, all vested parties must begin to minimize the effects of the barriers mentioned above.

This study was designed to deliver professional development in order to influence teacher TPACK for teaching mathematics with IWB technology. Prior research has successfully used the IWB to increase teacher TPACK. In a peer coaching study *Integrating the interactive whiteboard and peer coaching to develop the TPACK of secondary science teachers*, Jang (2010) concluded that the IWB enhance science teachers TPACK as well as their ability to integrate technology with their teaching. The current study addressed the professional development barrier to technology integration. The remaining variables; resources, teacher attitudes, and institutional support were not directly addressed in this study. Although, efforts were made to reduce the impediments of a lack resources and administrative support these barriers undoubtedly affect teacher technology acceptance. It is therefore suggested that if teachers receive professional development to teach mathematics with the IWB that focuses on TPACK their TPACK for teaching mathematics with the IWB will improve.

Research Questions

The purpose of this study is to examine the effects of a TPACK professional development for using IWBs on teacher TPACK for mathematics teaching with IWB technology. To fulfill this purpose mathematics teachers in a Central Texas School district underwent three weeks of professional development to assist them with teaching mathematics with the IWB.

1. What is the influence of a three-week Teaming to Teach with Technology (TTT) Interactive whiteboard professional development on middle school mathematics teacher TPACK in an urban middle school?
2. Does student achievement increase when Teaming to Teach with Technology (TTT) professional development for using the IWB is introduced to mathematics teachers in an urban middle school?
3. Is urban middle school student mathematics achievement differentiated across race after teachers receive three-weeks of IWB Teaming to Teach with Technology (TTT) professional development?
4. What are the barriers to integrating the IWB in mathematics classrooms in an urban school?

Significance of the Study

Learning to teach and learn with technology requires educators to utilize their intellect, creativity, imagination, and courage (Jacobsen, Clifford, & Friesen, 2002). Technology alone is not sufficient for effective teaching and learning (Greiffenhagen, 2000). The effective use of IWBs, much like many other technologies, requires knowledge and skills that emphasize how technology and pedagogical content knowledge work together, rather than in isolation. There is little quantifiable evidence to substantiate the claim that the IWB is the sole contributor to student engagement and achievement (Smith, Higgins, Wall, & Miller, 2005). However, the IWB is more than a presentation device, and should be used in association with ICT tools to increase content rich discourse with and amongst students (Greiffenhagen, 2000). TPACK may help educators choose appropriate ICT tools, as well as create and present lessons that exploit the affordances of IWBs to teach effectively. Teacher technology mediated instructional practices were addressed in this study. In particular teacher's use of the IWB to teach mathematics was investigated.

Because the IWB is a transformative technology that has replaced the chalk or dry erase board commonly associated with the traditional classroom, many teachers receive these technologies and continue to present their lessons in the same manner as before unabated by the capabilities of this dynamic educational medium. The learning capabilities encompassed by the IWB and other technologies cannot remain untapped, because student learning can be drastically enhanced by the exploitation of the full functionality of these tools. There are currently many models of professional development, however the number of technology professional development models has only began to increase over the last few decades. More studies are needed to inform the practice of teacher technology professional development in the future. Teacher knowledge to teach with technology is regarded as a major educational concern, due to the influx of federal funding to support technology integration in the classroom. Therefore, increasing teacher TPACK much like increasing teacher PCK is a major educational concern.

However, this is only one of a small number of studies that investigated the influence of professional development on teacher TPACK (Chai, 2010; Chai et al., 2010; Graham, 2009; Schmidt et al., 2009; Shin et al., 2009). There are currently many models of professional development, however the number of technology professional development models has only began to increase over the last few decades. More studies are needed to inform the practice of teacher technology professional development in the future. The results of this study will expand the current knowledge based in professional development design, as well as, mathematics instruction with technology.

Assumptions and Limitations

Because behavioral research is not conducted in a vacuum some elements of every study are beyond the control of the researcher. This section presents the assumptions and limitations of this study. A self-reported measured was used to collect participant TPACK data. Several assumptions and limitations were necessary to complete this study. The first assumption was that the methods of assessing the effects of the professional development were valid and reliable. The effects of the professional development were assessed through two instruments that were developed by other researchers investigating si1milar issues; both assessments were evaluated for reliability and deemed valid based on the constructs of the individual investigation sample. The instruments themselves are neither valid nor reliably because they are a product of the sample under investigation, but these previous administration did generate good internal consistency for the sample under investigation.

The second assumption was that the participants answered the questions on each assessment honestly and completely. It is also assumed that any assistance that took place during the professional development was administered in the same manner across the different professional development activities.

Two limitations existed in this study. The first limitation to the methodology is sample size. The construct validity of the items on the *Modified survey of teacher knowledge to teach with technology* was proposed to be accessed by means of a confirmatory factor analysis. This analysis is highly dependent upon a large sample size for the estimation to converge. If a large sample size is not present then the confirmatory factor analysis is not possible. Secondly, the number of observable characteristics available to calculate propensity scores needs to be large enough to match the treatment and control group as close as possible. If the number of characteristics is not sufficient then differences in the unobserved characteristics are part of the selection bias that is referred to as hidden bias (Rosenbaum, 1998).

The second limitation of this study is that all of the IWB technologies used in the study were not the same. Although the functionality of the different IWBs is quite similar, one of the technologies is permanently affixed in the classroom and the other was portable. This creates issues of sustainability and continuous use in the classroom, may have influenced the outcome of this study. Because this study utilized a convenience sample of teachers it was not feasible to increase the sample size, because more participants that had access to IWB simply did not exist.

Nature of the Study

This was quasi-experimental study conducted to inform teacher technology professional development, to influence teacher knowledge to teach mathematics with technology, and to support student mathematics achievement. As an applied research study, current research on technology professional development and teacher TPACK was used to investigate the effects of professional development on teacher knowledge and their student’s mathematics achievement.

Summary

The NCLB legislation emphasized the importance of continued technology professional development in U.S. schools. The legislation however, did not explicitly describe the types of technologies that teachers should use, or the type of professional development activities teachers should experience. The quasi-experimental research design used in this study was used to examine teacher knowledge to teach mathematics with interactive whiteboards. The study took place in a Central Texas school district. The middle school mathematics curriculum was the focus of the study. The results of this study were gathered through teacher surveys and the 6th through 8th grade mathematics section of the TAKS. All data were analyzed in SPSS® version 16.

CHAPTER II

LITERATURE REVIEW

This chapter synthesized current literature on the most effective means of increasing teacher knowledge to teach mathematics with IWB technology. The first half of this chapter answers several questions: (a) why is technology important for mathematics teaching and learning? (b) What type of teacher knowledge is needed to teach mathematics with technology? and (c) How can professional development assist teachers in gaining the knowledge needed to teach mathematics with technology? The later half of the chapter proposes a framework for fostering teacher knowledge to teach mathematics with the IWB, the essence of the dissertation study.

The evolution of applied mathematics has opened the doors to an enormous array of advanced technologies. Likewise, the evolution of technology fostered advancement in the teaching and learning of mathematics. This section chronicles the influence of technology on mathematics teaching and learning, as well as, student achievement. In the discussion that follows technology and mathematics was addressed from a policy, curriculum and pedagogy, and achievement perspectives. The educational policy that directed the use of technology in the mathematics classroom was important because this can dictate how technology was utilized in the mathematics classrooms. The curriculum and pedagogy were addressed because in conjunction curriculum and pedagogy determine what is taught in mathematics, and how it was taught. The final component of this discussion was achievement, which was a major concern for educators and policy makers, alike.

Educational Policy

Educational policy makers recognized technology integration was a major contributor to student success in mathematics across the United States. This is affirmed in the recent policy statements from many national and international educational organizations in support of the use of technology in all classrooms and in mathematics classroom in particular (ISTE, 2008). The NCLB legislation specifically addresses the importance of technology and teacher training to use technology. The Enhancing Education through Technology Act of 2001 is a subsection of the NCLB legislation that specifies that one of its purposes is to " provide assistance to States and localities for the implementation and support of a comprehensive system that effectively uses technology in elementary schools and secondary schools to improve student academic achievement"(USDE, 2001, ¶ 1). Although this statement encompasses all academic areas, mathematics is a high priority of educational policy makers, thus considerable efforts were made to infuse technology in mathematics classrooms to adhere to this section of the NCLB legislation. As a result of the NCLB legislation, educators began to brainstorm how to reorganize their current education models to take full advantage of the affordances of digital technologies (USDEb, 2004). To support these reorganization efforts other federal funding agencies provide research funding to support the research and development of activities and programs to assist classroom teachers with research to guide their practice. A large portion of the funding for mathematics education research to support technology integration can be traced back to the National Science Foundation (NSF). The NSF funds educational research projects that meet certain research requirements that are often times aligned to current educational legislation. Thus, as technology use became an educational concern on the national level more research to further substantiate these claims was needed. Educational practitioners use curriculum developers and mathematics expert's reviews of research studies to create curricula materials that are used by practitioners.

The majority of the educational policy concerning mathematics in the United States suggests that technology is an integral part of mathematics teaching and learning. As mentioned earlier, these policies influence whether or not technology is present in the mathematics classroom, not how it is used in the classroom. To address how technology is used in the classroom one must consult the current mathematics education authorities the National Council of Teachers of Mathematics (NCTM) standards (NCTM, 2000), and the International Society of Technology in Education (ISTE) National Education Technology Standards (NETS) (ISTE, 2000). According to NCTM "technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (p. 24). The ISTE expresses similar sentiments in its National Educational Technology (NET) Plan, which states that its purpose is to "enable stakeholders in K-12 education to develop national standards for educational technology that facilitate school improvement in the United States" (ISTE, 2000, ¶ 3). These documents provide the initial rationale for technology integration in the mathematics classroom, but how the technology is integrated is better understood by examining current mathematics curriculum and pedagogy for teaching with technology.

Curriculum and Pedagogy

Educational professionals work tirelessly to exploit the affordances of technology in the mathematics classroom, because of present and future educational benefits of various technologies. Mathematics teaching practices should be effective whether delivered in a technology rich environment or not, but non-digital resources have limits that do not exist in the digital world. Analog or non-digital manipulative resources do not allow the user to manipulate them with the same pinpoint accuracy and precision that is present with digital resources. This ability facilitates the transition from concrete to abstract. For instance, it is common practice to use different manipulatives to increase student conceptual understanding of abstract mathematical ideas. However, many common manipulatives, such as, algebra tiles and base ten blocks now have virtual counterparts. Should teachers simply replace the handheld manipulatives with the virtual ones? Or, should other factors be considered before completely discarding the non-digital instructional materials. Although this dilemma creates another dynamic to the integration of technology in the mathematics classroom, digital technologies afford teachers the opportunity access and create manipulative materials that do not exist or are impossible to create in a non-digital medium. Digital technology also addresses several other curriculum and pedagogical issues that cannot be addressed by traditional instructional practices. Digital technology is therefore an appropriate tool to support mathematics curriculum and pedagogy. Mathematics curriculum and pedagogy is therefore enhanced through the: (a) development of dynamic connections, (b) utilization of sophisticated tools, (c) creation of resource rich-mathematics communities, (d) construction of new design tools, and (e) exploration complexity through digital tools (Rubin, 1999).

Dynamic Connections

Digital technologies can enable students to develop dynamic connections to abstract concepts and ideas in mathematics through multiple representations. These dynamic connections allow educators to make the intangible, tangible for many young learners struggling to comprehend the complexities of mathematical concepts. Dynamic Connections to mathematics are most commonly seen in the area of geometry. Dynamic Geometry Software (DGS) is a prime example of how technology affords educators the opportunity to make dynamic connections in the classroom. Three of the most popular DGS applications are Geometer's Sketchpad®, GeoGebra®, and Cabri ®. These software packages allow educators to present complex geometric ideas through interactive digital pictures that are difficult to construct on a whiteboard or overhead projector with the level of precision necessary to present many of the concepts effectively given the short amount of instructional time allowed in many classrooms. The use of DGS in the classroom was well documented (Hölzl, 1996; King & Schattschneider, 1997). This type of technology integration has an established body of literature to substantiate its importance in the mathematics classroom. For instance, DGS integrated thoughtfully with curriculum and pedagogy produces measurable learning gains in the mathematics classroom (Hadas, Hershkowitz, & Schwarz, 2000; Laborde, 2001; Mariotti, 2000). One of the most highly recognized advantaging of DGS applications is the interactivity, which was realized through the dragging facility of the objects in the software package (Arzarello, Olivero, Paolo, & Robutti, 2002). Students can also take advantage of the construction and design capabilities of DGS applications (Hadas, Hershkowitz, & Schwarz, 2000). Yet, another advantage of DGS applications and technology integration in general was the exposure of young children to sophisticated technology tools.

Sophisticated Tools

Technology in the mathematics classroom exposes students to sophisticated mathematics tools that are commonplace in the postsecondary arena, as well as, the professional world. These tools include graphing calculators, spreadsheets, and other data processing tools that simplify complex computations. Of these the calculator can be considered the most controversial.

In the early stages of technology integration one of the major arguments concerning the integrations of sophisticated technology tools was whether not calculators inhibited student understanding of number and quantitative reasoning. Calculators are now commonplace in many mathematics classrooms and in students' everyday lives, therefore it is important that educators begin to use calculators to do more than just computation activities. In a pivotal meta-analytic study of over 80 research studies concerns the influence of calculator use in the mathematics classroom it was concluded that students who use calculators in their mathematics classrooms had better mathematics self-efficacy, self-concepts, and improved mathematics achievement given the appropriate circumstances (Hembree & Dessart, 1992). Establishing the appropriate circumstances for calculator use has remained elusive, however, the recent research suggests that calculators are appropriate learning tools for K-12 mathematics (Groves & Stacey, 1996; Groves, 1997; Ruthven, 1998; Scheuneman, Camara, Cascallar, Wendler, & Lawrence, 2002). Aside from calculators, spreadsheet use in the classroom exposes students to technology commonly used in the workplace and helps to create concrete conceptual connections to abstract mathematical ideas.

Research on the use of spreadsheets in the classroom has historically concerned the teaching of algebraic concepts and statistics (Levin & Abramovich, 1992; Sutherland & Rojano, 1993). Capponi and Balacheff (1989) found that students lacked the ability to transfer their algebraic knowledge into the spreadsheet environment. However, several subsequent studies indicated that given the right classroom conditions and instruction, students could use spreadsheets to explore many algebraic concepts while making concrete connections between the spreadsheet applications and algebra (Abramovich & Nabors, 1997; Ainley, 1996; Healy, Pozzi, & Sutherland, 2001; Rojano, 1996). Earlier research on the vitality of using spreadsheets to teach statistics was similar to early research on spreadsheet applications for algebra learning, in that they both were met with initial skepticism. Nash and Quon (1996) found that students had difficulty following the calculations presented in the spreadsheet applications, and that many of the applications graphing capability were less than impressive for statistical analysis purposes. However, the majority of the research concerning the vitality of spreadsheets in the mathematics classroom from the last decade or so indicates that the spreadsheet, if implemented correctly, is a great tool for illuminating algebraic and statistical concepts that are hard to follow visually, while directly connecting the student to the sophisticated tools of the workplace (Baker & Sugden, 2003; Kieran & Yerushalmy, 2004).

Resource-Rich Mathematics Communities

The Internet paired with a personal computer is the hub of a resource-rich mathematics community with limitless potential. Teachers can use the hub to discover and share digital resources instantly, which widens the boundaries for mathematics teaching and learning in the classroom. The digital resources available through the hub include virtual manipulatives, flash applications, and various other digital as well as analog or non-digital educational resources. Aside from the educational resources available for students through the Internet, many other opportunities were possible. Some of these opportunities included: (a) on-line professional development for teachers, (b) mathematical communities for students, and (c) home-school connections for parents (Rubin, 1999). The most current research suggested that Internet resources were under used, and under appreciated (Frid, 2001; Gerber, Shuell, & Harlos, 1998; Jones & Simons, 1999; Mioduser, Nachmias, & Lahav, 2000) with regard to mathematics teaching and learning. The Internet has plenty of applications that force student to interact with each other and create original thought. For instance, instead of having students write a research paper teachers could have students create a Wiki. Although current research suggests that the Internet is currently under-used and under-appreciated (Lenhart, Purcell, Smith, & Zickuhr, 2010) it is the cornerstone of many resource-rich mathematics communities nonetheless. Technology in the mathematics classroom can also be used for the construction and design of new tools.

Construction and Design Tools

Computers allowed students to move beyond the construction of their mathematical knowledge to facilitation of creative projects and designs that exemplify the conceptualization and application of mathematics in the real world. Programming languages like Logic Oriented Graphic Oriented (LOGO) are well established in the literature on mathematics education. LOGO is a functional programming language that allows students to create and interact with objects that are visible and quantifiable, while adhering to conventional mathematics and building connections between spatial and numeric/algebraic thinking (Jones, 2005). Construction and design tools like LOGO help facilitate student learning and promote problem solving. The research on the use of LOGO in mathematics classrooms dates back to the 1970's, yet the impact in the mathematics classroom remains. The early research on LOGO in the mathematics classroom concentrated on the development of a theoretical framework to describe the importance of student-controlled interactions with technology for mathematics learning (Papert, 1970; Papert, 1972; Papert, 1980). Latter research address the lack of evidence supporting the impact of LOGO on the learning of mathematics (Clements, 1985). The concerns of the early skeptics were addressed in a series of studies that identified the many benefits of LOGO for mathematics teaching and learning (Clements & Sarama, 1993; Hoyles & Sutherland, 1989; Weir, 1987). The LOGO programming language can be used to teach, as well as reinforce concepts in diverse mathematics disciplines, such as: (a) algebra, (b) geometry, and (c) statistics (Gorman & Bourne, 1983). However, the effectiveness of LOGO and other forms of technology integration are highly dependent on the manner in which they are utilized in the mathematics classroom that is on the skills the teacher possesses for teaching the content through the LOGO environment.

More recently teachers have began to utilize MatLab® as a substitute for the LOGO programming language. MatLab® was more relevant than LOGO because it was a programming language that was used by engineers in the workplace. The transition to MatLab® coincides with the push for more Science, Technology, Engineering, and Mathematics (STEM) educational opportunities for students. MatLab is currently the most comprehensive software package to generate simulations in mathematics, science, and engineering (Ibrahim, 2009). Unlike LOGO MatLab is currently used by engineers in the professional world, this makes a much more practical tool for teachers. Because MatLab is a tool that is used by engineers STEM teachers can use this tool in their classes and engage their students in authentic engineering task. Teachers are the medium by which the interactions between technology and mathematics are controlled, thus in order to bring effective teaching with technology to fruition, teacher knowledge to teach with technology must be examined.

Teacher Knowledge to Teach Mathematics with Technology

Pierson (2001) suggest that effective technology integration can be defined as the intersection of technological knowledge, pedagogical knowledge, and content knowledge. This type of knowledge is especially important for mathematic teachers because of the complex nature of mathematic content, pedagogy, and associated instructional technologies. The intersection of the aforementioned types of knowledge is identified as Technological Pedagogical Content Knowledge (TPACK). However, in order to understand TPACK it is imperative that each component is dissected and explained thoroughly. The first component is content knowledge. Content Knowledge (C or CK for short) is knowledge about the actual subject matter that is to be learned or taught (Mishra & Koehler, 2006, p. 5) Content knowledge is the amount and organization of knowledge in the mind of a teacher, and pedagogical knowledge is more or less content or subject matter knowledge for teaching (Shulman, 1986). In terms of mathematics content includes: (a) algebra, (b) geometry, (c) statistics (d) calculus, and all other types of mathematics. These types of knowledge are among the most basic understanding necessary for teaching mathematics. The second type of knowledge pedagogical is the understanding of how to teach the content.

Pedagogical Knowledge "(PK or P for short) is deep knowledge about the processes and practices or methods of teaching and learning and how it encompasses (among other things) overall educational purposes, values and aims" (Mishra & Koehler, 2006, p. 6). Pedagogical knowledge is necessary because it is not enough to understand the mathematics content, teachers must also possess the knowledge of student misconceptions as well as the many other aspects of pedagogy. The concept of TPACK is an extension of Pedagogical Content Knowledge (PCK) conceptualized by Shulman in the mid 1980's (Shulman, 1986). The intersection of these two types of knowledge yields PCK. Furthermore, PCK is described as the "most regularly taught topics in one's subject area, most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations—in a word, the ways of representing and formulating the subject that make it comprehensible to others" (p.9). Pierson (2001) adapted Shulman's PCK to include technological knowledge thus conceptualizing TPACK. Pierson suggest that effective technology integration can only be achieved through the development of the intersection of pedagogical knowledge, content knowledge, and technical knowledge.

Mishra and Koehler (2006) elaborated on the initial conceptualization of TPACK by describing each type of knowledge in isolation to present a fully developed model of TPACK. Originally TPACK was develop under the acronym TPCK, but this was revisited at the 9th Annual Technology Leadership Conference. The consensus was that the previous acronym did little to support the framework conceptually, thus the leadership committee decided that TPACK was more appropriate. Specifically "it emphasizes, through the letters, the three kinds of knowledge (Technology, Pedagogy And Content) that we believe are essential building blocks for intelligent technology integration. Second, and as important, it captures the fact that these three knowledge domains should not be taken in isolation, but rather that they form an integrated whole, a "Total PACKage" as it were, for helping teachers take advantage of technology to improve student learning" (Thompson & Mishra, 2008, p. 38). Although the addition of the letter A to the framework was significant the greatest accomplishment was the addition of technology into the Shulman's original PCK framework.

The "T" in TPACK represent technology and is very important to the TPACK framework. Mishra and Koehler (2008) suggested that: "Technology knowledge (T or TK) is knowledge about standard technologies such as books and chalk and blackboard, as well as more advanced technologies such as the Internet and digital video" (p.4)

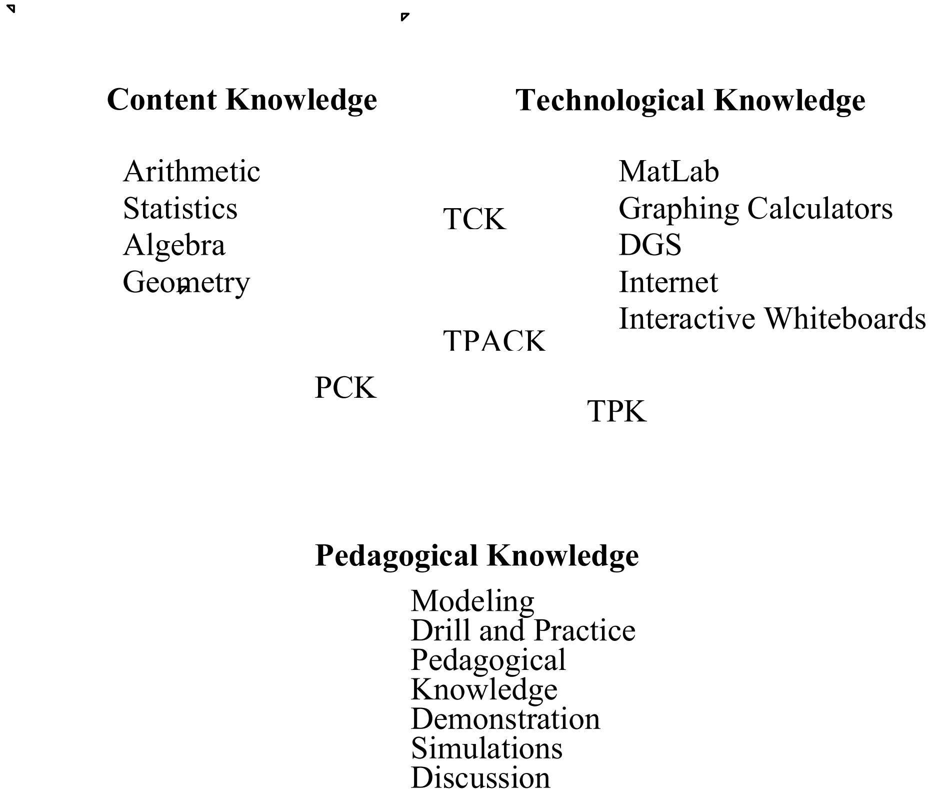
According to Mishra and Koehler (2008) teacher must understand how to used all technologies at their disposal effectively. These are both analog (non-digital) as well as the digital technologies. Technology is important because of the many affordances that technology provides for teaching and learning. Yet, this benefits are not without boundaries.

Technological knowledge, content knowledge, and pedagogical knowledge all afford and constrain one another. These affordances and constraints take place at the intersections of all these different types of knowledge. Thus, Mishra and Koehler (2008) suggest that the intersection of PCK, TCK, and TPK is TPACK and this type of knowledge is vitally important for teaching with technology. Shulman conceptualized PCK, but Mishra and Koehler (2006) concluded that just and it is important for teachers to understand how pedagogy knowledge supports and constrains content knowledge the same is true with technology and content as well as technology and pedagogy. Technological Content Knowledge or TCK is the knowledge of how technology enhances the teaching of content. This type of knowledge is necessary for teachers because it supports decision choose appropriate technologies to support specific content learning. Likewise, this knowledge can help teachers avoid using inappropriate technology to teach content that is constrained or hindered by the use of technology. Similarly Technological Pedagogical Knowledge or TPK assist teachers in better understanding the affordances and constraints of technology on pedagogy. Teachers TPK helps them to design lesson and activities that use technology to assist in the acquisition of the content. Pedagogical activities that support learning like simulations can be delivered via technology and TPK helps teacher facilitate these activities.

There were several unique features of TPACK that suggested it should be seriously considered in the development of a model for technology integration. The different sets of knowledge and skills that TPACK encompasses requires an understanding multiple representations of concepts using technologies; constructive pedagogical techniques that apply differentiated instructional technologies to meet the needs of all students; knowledge of nuances of particular content areas that make them difficult for students to comprehend and how technology can assist with student acquisition of the concepts; knowledge of scope and sequence of content and epistemological assumptions; and knowledge of how technologies can be scaffold student content knowledge (Harris, Mishra, Koehler, 2007). One question worth answering at this point is how does this framework fit into the traditional mathematics classroom setting? Figure 1, as seen below is an example of a model of how TPACK could be applied in a mathematics classroom. The model presents some of the mathematics content commonly seen in the Middle grades. Several example of the types of technologies seen in the middle grades are also presented. This model also suggest some pedagogical strategies that can be seen in the typical mathematics classroom. This model however is not all encompassing, and other elements could be added as well. Content knowledge or CK in this middle school mathematics model entails arithmetic, algebra, statistics, and geometry. These subjects are the basic middle school content students will encounter, thus they were included in this model. Like wise middle school teachers should have some knowledge of middle grades appropriate pedagogy such as: (a) demonstrations, (b) discussions, (c) drill and practice, (c) modeling, and (d) simulations. These activities facilitate the teaching of the middle school content, but the technological knowledge or TK supports both the Content Knowledge as well as the pedagogical knowledge. The major categories of content, pedagogy, and technological knowledge intersect to create the subcategories of TCK, PCK and TPK, which intersect to create TPACK. The intersections are much more difficult to express in the model because they constantly change depending on the combination of content, pedagogy or technology involved. For instance, TCK for arithmetic knowledge is enhanced or constrained differently for graphing calculators and interactive whiteboards. Thus at the intersections of this model is where teachers must development and extent their knowledge and skills the most.

If technology is integrated through TPACK there will be a strong connection to teaching, learning, and student achievement that exploits the affluences of technology to benefits all stakeholders. In conclusion TPACK may provide a useful framework to analyze and monitor teaching practices of integrating technology. However, before these practices can be monitored it is important to provide teachers with the appropriate model of these intersections through professional development.

Figure 1. Example of TPACK for middle school mathematics teaching and learning



Technology and Student Achievement

The influence of technology on student achievement was and remained a major national concern. Thus, several large-scale investigations were launched to examine empirically the connection between technology used in schools and student achievement. Although many studies investigated achievement across several disciplines, but for the purpose of this dissertation only mathematics achievement was considered. The foundational work in the area of technology and mathematics achievement was *Does It*

*Compute? The Relationship between Educational Technology and Student Achievement in Mathematics (*Wenglinsky, 1998*).* Based on a national sample of students from NAEP, Wenglinsky found that technology can improve student achievement if used meaningfully in problem solving rather drill task. Wenglinsky investigated technology use in schools in relation to social class and different ethnic groups. The results indicated that technology did have a positive influence in many cases, but the influence of technology on student achievement was highly dependent on how the technology was used in the classroom. Specifically the level of computer use does not matter, but extreme levels of use may be unproductive if the tasks are not meaningful. Further, when computers are used to do productive task and in association with teachers that are technically literate there were significant gains in mathematics achievement (Wenglinsky). A more recent examination of the *Usage of computers and calculators and student achievement: Results from TIMSS 2003* revealed a link between computer/calculator use and student achievement.

Calculators and Computers were the technology tools under investigation for the 2003 TIMSS international study. Antonijevic' (2007) found that the influence of calculators and computers on student achievement differed from country to country, but for the most part the influence was not substantial. The study however does not address how the calculators or computers were used, but rather the quantity of the usage in the classroom. This is one of areas where Antonijevic feels the study could be improved, but the survey instrument used in the study did not address these types of questions. The results of 1998 NAEP study and the 2003 TIMSS large-scale studies support the general consensus concerning technology and student mathematics achievement, which is that it is not the technology but how the technology is used that makes the difference in student achievement (Antonijevic, 2007; Wenglinsky, 1998).

Teacher technology use is a major concern for teachers, administrators, and researchers. Hannafin and Land (2002) conclude that some basic assumptions must be made in order to promote the effective use of technology in the classroom. According to Hannafin and Land the use of technology in the classroom must follow the assumption of the instructional activity system. The instructional activity system assumes that instruction is effective when lessons and teaching assume the following elements are paramount: (a) learning content, (b) learning activities, (c) interactions between other instructional practices, (d) data driven evaluation and revision, (e) assessment, and (f) teacher professional development (Hannafin & Land, 2002). Thus, when technology is introduced into this system all parties must assume that the aforementioned elements remain of paramount importance in order to be effective. Teacher professional development is a viable medium to support the effective use of technology in the classroom. So much so, that is an assumption of the instructional activity system, and can support the effective use of technology according to Hannafin and Land.

Professional Development

Professional development, staff development in the mid to late 1970s, had been paramount for precipitating change, but what exactly is professional/staff development? . Throughout early literature on professional development the terms staff development and professional development are consistently used interchangeably. Beeler (1977) describes staff development as “in-service continuing education or staff training, designed to enhance the competences, skills, and knowledge of individuals and to enable them to provide better services to their clientele” (p. 38). Merke and Artman (1983) provide a more recent definition of professional development, which asserts that professional development is “a planned experience designed to change behavior and result in professional and/or personal growth and improved organizational effectiveness” (p. 55). One definition for professional development is “any activity that is intended partly or primarily to prepare paid faculty members for improved performance in present or future roles in the school district.” (Little, p. 491). This definition suggest that professional development is an isolated event, but it is more appropriate to describe it as a series of events of process that leads to improved performance. According to Guskey teachers’ beliefs and self-efficacy are changed as a result of professional development through a process. Guskey defines professional development as; a planned experience that changes a teacher’s classroom practices to foster a change in student learning outcomes that subsequently alters teacher beliefs and self-efficacy. This definition does pose an important question. What can be considered an experience?

Experience is used here to represent one of the five established models of professional development. Loucks-Horsley, Harding, Arbuckle, Murray, Dubea, and Williams (1987) suggest that the entire spectrum of professional development activities can be encompassed by five models: (1) individually-guided staff development, (2) observation/assessment, (3) involvement in a development/improvement process, (4) training and (5) inquiry. These models describe the different types of professional development that take place in schools along with their processes and activities.

This section describes the first of the five models of professional development. The first model is the individually guided staff development is a teacher lead learning activity that is informal in nature. These activities include reading research literature and drawing conclusions, group discussion concerning best practices of new policies, and experimentation with new teaching strategies. Individually guided staff development brings teachers together to address their needs specific to their campus or district, which can promote their professional development as individuals and as a group (Villegas-Reimers 2003). This model is cost-effective, because it is teacher driven. Furthermore, because this model is teacher driven teacher typically feel more vested in the outcome of the professional development.

The second model is an observation/assessment model is typically implemented to collect some form of data to use in the improvement of teaching and learning. This model typically falls under the umbrella of an evaluation model. Several subgroups fall under the evaluation model, one such subgroup is the clinical supervision model. This model is used to offer feedback and suggestion to particular areas of ones teaching. Under this clinical supervision model the administrator observes each teacher and takes notes to give feedback and suggestions for improvement. The impact of clinical supervision on teacher self-efficacy and performance is mixed (Pavan, 1983). Assessment is also increasingly used as a means of professional development. According to Danielson (2001) if assessment is to be used as a form of professional development evaluation must be used as a process and an ongoing system of feedback and support must be available to teachers. Although this can be a powerful professional development model, many teachers associate this model with personal evaluation, which can increase teacher decent (Loucks-Horsley et. al).

The third model of professional development is involvement in a development/improvement process. This model is typically implemented to solve a problem and can include development or adaptation of curriculum, designing programs, or systematic school improvements to enhance classroom instruction and/or curriculum (Loucks-Horsley et al). Teachers engage in readings, discussions, observations, or in extreme cases trial and error to solve problems (Sparks & Loucks-Horsley, 1989). This model is supported by the assumption that adults learn better when they are vested in solving the problem (Knowles, 1980). This model also allows teachers to work together to solve the problems that will ultimately support the improvement of their schools that helps to engage the teachers.

The forth type of professional development is training. Training is synonymous with staff development for many teachers. One possible explanation why educator have developed this association is that the typical training session is conducted with a cleat set of objectives with which educators have become accustomed to in professional development session (Loucks-Horsley et al). This model although the most popular of the professional development models, is also the most highly scrutinized professional development model. The duration of many training models is the cause of much of the concern with the effectiveness of the model. However, as professional development has become recognized as an ongoing process more researchers have began to transition from one day workshop to more extensive learning activities prolonged over several meetings with much success (Ball, 2000; Irving, Dickson, Keyser, 1999). The final model suggested by Loucks-Horsley et al is inquiry.

The fifth and final model is the inquiry model that is also described as an action research model. According to Loucks-Horsley et al. (1989) inquiry model operate under three assumptions: (a) teachers are intelligent, (b) teachers are inclined to pose and search for answers to questions, and (c) teachers will develop new understandings when in engaged in constructivist activities.. Nonetheless, effective professional development should exemplify certain characteristics. In the section that follows some characteristics of successful professional development are presented, as well as, rationale for why these factors influence the effectiveness of professional development.

What Makes Professional Development Effective?

The professional development literature is swamped with a plethora of best practices. Each of these best practices offer differing opinions on the elements that influence the effectiveness of professional development programs. In this section several views of effective professional development are offered followed by an examination of the empirical evidence supporting the components of effective professional development.

One reason for the many opinions on what makes professional development effective is that professional development is complex because it does not take place in a controlled setting. Because the settings and questions differ from scenario to scenario professional development leaders must consider many factors in the design process. Lee

(1993) argues that effective professional development must be constructed in ways that deepen the discussion, open up the debates, and enrich the array of possibilities for action. While Guskey and Sparks (2004) suggest that it is important to take into account the complex nature of the relationship between professional development and student outcomes. Both of these views of effective professional developments are highly dependent on the affects of several factors surrounding the design and implementation of professional development programs.

The factors that influence the effectiveness of professional development can be categorized into two general categories: (a) teacher specific factors and (b) process dependent factors. Teacher dependent factors concern the particular needs of teachers, while the process factors are account for the implementation of the professional development. To begin it is important to identify the teacher specific factors. Darling-Hammond and McLaughlin (1996) present an exhaustive list of teacher specific factors to include in a professional development. The researchers suggest that the professional development must: (a) engage teachers in practical tasks with opportunities to observe evaluate and reflect on the new practices, (b) directly reflect the work of teachers and their students, (c) be collaborative and involve the sharing of knowledge, and (d) be connected to aspects of school change (Darling-Hammond & McLaughlin). These factors are directly related to the needs of teachers. Teacher specific factors such as the factors presented above help to promote teacher support for the professional development activities by situating the activities in a context that is directly associated to the teacher. The Process standards describe the processes and activities that take place during the professional development.

This section describes the background and prior research on the professional development process standards, and then attempts to identify some key examples of these processes. According to Guskey (1995) developers should recognize that change is an individual, as well as, organizational process. Processes should be designed to address large outcomes by addressing smaller issues that will support the overarching outcome. Thus, in planning an implementation process for professional development think big but start small. He also suggested that including procedures for feedback and support is one of the most important elements in developing a successful professional development (Guskey). There are many ways of delivering professional development. Recently, extra emphasis has been placed on creating opportunities for teachers to engage in active learning activities during professional development. Garet, Porter, Desimone, Birman, and Yoon (2001) found that professional development is more likely to produce enhanced knowledge and skills when it focuses on content, provides teachers opportunities for active learning, and is situated in a school context. Furthermore, connecting professional learning and practice is important for successful professional development (Lee, 2004), and this is very evident in the area of teaching and learning with technology in the classroom. Although this list does not include each and every teacher related factor that influences professional development, this list does include a broad spectrum of the teacher related factors. The ideas of thinking big and providing feedback as a mechanism of optimization support the specific professional development processes presented below.

The process dependent factors associated with professional development are slightly more difficult to enumerate, but include: (a) the type or model of professional development, (b) the length or duration of the activity, and (c) organization of delivery. The types or models of professional development were discussed earlier so the remainder of this discussion will focus on the length of the professional development and its organization.

Time is a crucial element for any improvement process, and is likewise an important factor in the effectiveness of professional development (Easton, 2008). The length of a professional development program is important for many reasons, but two reasons will be discussed here in detail. Teacher need time to incorporate the practices of the professional development into their daily routine (Bush, 2001). It is very likely that teachers will need some time to develop an concrete understanding of the new concept or techniques presented in the professional development, as well as time to become fluid with their newly acquired skills. This process will take considerable time for the teacher to experiment and refine how the technique will be used in the classroom. A second element of time that is crucial to professional development is time for the teacher to experience the benefits of the change.

The benefits of professional development can be realized in many ways, but the teacher must have time to see results to fully appreciate the newly acquired knowledge or skills (Dorph & Holtz, 2000). This benefit of time is closely aligned with the “model of the process of teacher change" (Guskey, 1986, p.7). According to Guskey's model teachers beliefs and attitudes are changed as a result of professional development through a process. This process is linear and consists four steps: (1) staff development, (2) change in teacher's classroom practices, (3) change in student learning outcomes, (4) and change in teacher beliefs and attitudes. After a sustain period of time teachers will realize that the professional development has made a difference and will begin to incorporate the activities into their natural teaching process. Thus, the teacher progresses through each of these steps in a linear fashion until they see results of their actions, which leads to a change in their beliefs. This process takes a considerable amount of time, but can be highly influential in the effectiveness of professional development activities within an organizational structure.

Organizing professional development to support collaborative professional development activities. These types of activities promote the collective participation of individuals from the same school or district. Organization in this discussion refers to the organization of the group for professional development delivery. This could range from a district wide initiative to a single department workshop. Many professional development activities take place district wide and include many different grade levels and subject areas receiving simultaneous instruction. There is little evidence to support the use of district –wide professional development delivery as an effective model of professional development, but "collective participation" has received considerable support. According to Cordingley, Bell, Rundell, and Evans (2003) reviewed recent professional development literature collective participation or collaborative professional development organization has the following positive effects: (a) increased teacher confidence, (b) stronger teacher beliefs in their ability to enhance learning, (c) a commitment to change and willingness to try new things, and (d) enhanced knowledge and practice. All of these benefits are part of the reason why professional development organization is very important. This discussion was devoted to examining some of the most common teacher specific and process specific factors associated with effective professional development, but do this same factors influence effective professional development for using technology in teaching and learning?

Professional Development to Utilize Technology

Technology has the potential to enhance student learning inside and outside of the classroom, but with these enhancements comes dramatic changes in the professional knowledge teachers needs to use them effectively (Stein, Ginns, & McDonald, 2007). Some advocate that technology integration has yet to influence teaching and learning because of the numerous barriers to the integration of technology (Bariso, 2003; Pajo & Wallace, 2001). As mentioned earlier, the impediments to technology integration can be categorized by the following: (1) resources, (2) institutional and administrative support, (3) training and experience, and (4) attitudinal or personality factors (Brinkerhoff, 2006). Each of the barriers previously mentioned are equally important to the integration of technology in general, but changes in teacher knowledge and practice can influence student learning. Intensive professional development can change teacher knowledge and practice (Borko, 2004). Teacher knowledge is vital for student learning, but further research is necessary to better ascertain how professional development can promote the cultivation of teacher knowledge and practice (Dall'Alba & Sandberg, 2006). Plair (2008) suggests that despite a consistent wave of "how to" workshops and some longer-duration seminars, teachers have yet to infuse technology into the curriculum and classroom practices. The section that follows examines the elements that make professional development for teaching with technology effective.

What Makes PD for Technology Effective?

Technology integration is currently a major concern for educators, administrators, and researchers. Yet, despite the current technology integration agenda an effective model for professional development is far from established. Until several years ago the typical professional development program to integrate technology was more or less a technology training session. Researchers have nonetheless identified several components of technology professional development that are effective. Effective professional development for teaching with technology should: (a) not focus entirely on technical competencies, (b) focus on teacher content, (c) involve cooperative learning communities, and (d) allow time for skill mastery. Although technology is an important aspect of professional development activities designed to train teachers to teach with technology, the technology skills alone will not improve teacher practice.

King (2002) suggest that developers of professional develop activities for technology integration should avoid a strict focus on establishing technology competences. Instead King insists that professional development leaders should consider incorporating group discussions, cooperative learning communities, and curriculum development. Group discussions allow teacher to share strategies among one another and to discuss their difficulties with their peers. Likewise cooperative learning communities establish working relationships that foster peer technical and creative support. Finally curriculum development allows teachers integrate the technology into his/her routine, by incorporating the tool in to the curricular planning. This also prevents the tool from becoming a classroom novelty that is only used on occasion to "wow" the students. Teachers also need time to practice teach with the technology in a classroom simulated environment which provides an opportunity for reflection on ways to improve their instruction with technology (Niess, 2005; Niess, Lee, Sadri, & Suharwoto 2006).

All technology tools can either afford the educator with new and relevant opportunities or constrain the educator's ability to deliver instruction effectively. The only way for an educator to develop a conscious ability to decipher between uses of technology that exploit the affordances and those that impede progress is to give educators time to develop their new competencies in classroom situated activities (Sugar, 2005). Swan, Holmes, Vargas, Jennings, Meier, Rubenfeld (2002) created the Capital Area Technology and Inquiry in Education (CATIE) program to give educators opportunities to explore these competencies in a situated context. The program introduces technology experts in schools as mentors to teachers that want to infuse technology into their classroom activities. The researchers attribute the success of the program to the level of empowerment teachers receives from active learning about technology from situated classroom practice. For many educators the integration of technology is difficult, thus some research have found that providing just-in-time tech support is important for successful technology professional development (Hall, Fisher, Musanti, & Halquist, 2006; Plair, 2008).

Onsite technical assistances is important because many teachers need the reassurance that someone is on a call away to address any technology issues that may arise. This section examined the factors of professional development for teaching with technology that are effective. Some of these factors coincide with the factors that support effective traditional (non-technology oriented) professional development and professional development to teach with technology. There is heavy overlap in the areas of content focus, collaborative training organization, and program duration, thus these are the elements that received the highest priority in the design of the professional development program used in this study. The aspects of the IWB that support mathematics teaching and learning are presented in the section that follows.

The IWB and Mathematics Instruction

The IWB affords the mathematics instructor several instructional advantages. This tool utilizes a large touch screen area that controls computer content projected on to its viewable surface. The ergonomics of the IWB allow the user to adjust content using more than the standard point and click adjustments provided by the computer mouse. The IWB is more than a presentation device, and should be used in association with ICT tools to increase content rich discourse with and amongst students (Greiffenhagen, 2000). However this is not the only affordance provided by the IWB. In the sections below each of the many instructional affordances of the IWB for mathematics instruction is examined along with current an analysis of the current research concerning the best instructional practices with the IWB.

The Benefits of the IWB for Classroom Learning

The IWB has many benefits for the teaching and learning of mathematics. This section identifies several benefits of the IWB for mathematics instruction and critically analyzes the current research pertinent to each attributes mathematics benefits. One of the myths about the IWB is that it is an electronic dry erase board. A dry erase board shares many of the same affordances and constraints as an interactive whiteboard (IWB), however, the minute differences between the two technologies alter the specific TPACK needed to teach effectively. Both the dry erase board and the IWB provide allow the teacher to handwrite information on a large visible area in multiple colors and sizes. Teachers can also erase and modify the content in pretty much the same manner on either tool. However, the IWB allows teachers to almost effortlessly switch between different examples and representations because the content can be loaded in digital form so that the teacher can toggle between examples. Teachers using a dry erase board are constrained by their ability to rapidly create the pertinent content for each example, erase it, and create the next example. This is just one example of how PCK and TPACK must be bridged for effective teaching to occur. Another myth about the IWB is that it is little more than a mere display board or oversized computer monitor. The IWB affords teachers access to a wide array of motivating and contemporary resources (Winzenried, Dalgarno, Tinkler, 2010). However, there are several key features of the IWB that dispel this myth to include: (a) centrality in the classroom, (b) interactivity, (c) adaption to different learning styles, (d) the ability to record, and store materials (Glover & Miller, 2002). The first benefit of the IWB in the mathematics classroom is the large viewable area that serves as focal point for classroom discussion. Some of the current research concerning the functionality of the IWB in the classroom suggest that because the IWB is at the center of instruction teachers are more prone to create instructional exercises that are more authoritative rather than constructive in nature.

The centrality of the IWB in the classroom is both an affordance and a hindrance to mathematic instruction. The IWB's critics suggest that the tool promotes didactical rather constructive educational practices (Greiffenhagen, 2000; Malavet, 1998; Lee & Boyle, 2003. However, the ability of the IWB to allow the teacher to act as a mediator rather than a dictator, of the interactions between the instructional content placed on the IWB and the student is indicative of the social constructivist model of instruction (Warren, 2003). This is not to say that the IWB eliminates the role of the teacher in the classroom, contrarily the teacher's role shift to more of an "orchestrator". According to Wood (1998) the most effective learning takes place when the objective is intelligible, but not easily attainable without assistance. Their role can be seen as orchestrating the features so as to ensure that the activity proceeds fruitfully towards achievement of the planned learning objectives as well as completion of the task itself (Kennewell, 2001; John & Sutherland, 2005).

The large viewable area of the IWB and the plethora of tools available on the computer allow teachers to present complex instructional task that the entire class can discuss synchronously. This allows the teacher to engage the students in class discussions through dialogic teaching. This type of teaching allows teachers to "encourage students to participate actively, using whole-class and group-based discussions to articulate, reflect upon and modify their own understanding" (Mercer, Warwick, Kershner, Kershner, & Kleine, 2010, p. 369). In their study on using the IWB to develop a collaborative discussion space, Mercer, Warwick, Kershner, Kershner, & Kleine concluded that the IWB was a good discussion tool because data can be easily manipulated on the large screen the entire class can participate in the discourse and make suggestions that can be implemented instantaneously. The large interactive instructional area, also allows students in a mathematics classroom to construct their own knowledge. One of the major tenets of the constructivist theory is that the learner gains knowledge by actively participating in the learning process in order to build on existing knowledge often times in a collaborative socially mediated environment. Aside from promoting the construction of mathematics knowledge the IWB improves teacher pacing in the mathematics classroom.

Maintaining an adequate pace in a mathematics lesson is important to the overall lesson success, and the IWB supports lesson pacing as well. Mathematics more so, than many other educational content areas requires that the educator to organize the material in a manner that best suites the needs on the learners. This includes the use of peripherals, such as, manipulatives, calculators, rulers, protractors, etc. The need for these materials coupled with the nature of mathematics instruction, which as a discipline promotes the utilization of problem posing and discourse require the adequate use of all instructional time. Therefore, any time that could be saved in the question-posing component releases more time for discourse. The IWB influences the pace of lessons in several ways. Firstly, the pace of mathematics lessons is increased because the instructor does not have to expend time conceptualizing the next question, writing it on the board, or adjusting the peripheral accordingly to suit the next task (Ball, 2003; Miller, 2003). This in turn creates more class time to explore more examples and increase the depth of the discussion. This does not come without some drawbacks however. The questions that arise due to the nature of the IWB's flexibility may be difficult for some teachers to facilitate. However, the IWB does support the teacher by allow the teacher to filter questions and use alternative resources to answer questions. For instance, the IWB affords teachers is the unique opportunity to respond spontaneously to student curiosity or address misunderstandings by retrieving stored content from previous lessons, accessing unused content on the teacher's computer or by searching the internet (Haldane, 2007).

Depending on the teacher level of comfort with the IWB, teacher may not address the spontaneous questions that arise during classroom discussion because this will force the teacher to deviate from the order of the IWB presentation. In addition to the improvement of lesson pacing, the IWB also promotes the adaptation of lesson to meet the needs of a diverse population of learners. Teachers may use the ability of the IWB to record and save classroom interactions and activity as a mechanism to maintain lesson pacing when time is sensitive. The ability to save and recycle materials previously created or annotated reinforces and extends the learning over sequence of lessons (Smith et al., 2005; Walker, 2002). Because many concepts in mathematics can be abstract it is important for students to have the ability to review lesson materials and examples several times. Furthermore, having access to the previous lesson may help students build on prior knowledge, and help educators locate and diagnose misconceptions. As with all classroom technology the teacher's use of the technology is paramount. In an observation study of whole instruction of mathematics and literacy Wood and Ashfield (2008) concluded that "it is the skill and professional knowledge of the teacher that mediates interactions with technology and thus facilitates the development of pupils' responses to technology" (p. 84). A similar conclusion were found in a case study, *Teaching and Learning with an Interactive Whiteboard: A Teachers Journey*, a teacher named Sue found that it was not the IWB that made the difference in her teaching, but rather how she chose to use the IWB (Hodge & Anderson, 2007).

Thus, although the general features of the IWB promote good overall classroom learning and management skills, the more specific features that allow teachers to address the diverse learning needs of many students are dependent on the skills and knowledge of the teacher. These skills and knowledge types allow the teacher to utilize the IWB's ability to address multiple intelligences. Curwood (2009) recognizes the IWB's ability to address multiple intelligences as one of the tools major advantages because this allows the IWB to enable teachers to differentiate instruction. The efficiency, flexibility, and versatility of the IWB as a teaching tool allow the IWB to support the multiple needs of learners in each lesson (Glover & Miller, 2002; Smith, Higgins, Hall, & Miller, 2005).

The IWB has the capability to meet the instructional needs of a diverse body of learners by harnessing the affordances of multiple digital technologies that address multiple intelligences. A full examination of multiple intelligences is beyond the scope of this discussion, but this is a major benefit of the IWB, thus a brief overview of multiple intelligences is in order. The theory of multiple intelligences suggest that each human being is capable of "seven relatively independent forms of information processing, with individuals differing from one another in the specific profile of intelligence that they exhibit" (Gardner & Hatch, 1989, p. 4). These intelligences are: (a) linguistic, (b) logical-mathematical, (c) spatial, (d) bodily-kinesthetic, (e) musical, (f) intrapersonal, and (g) interpersonal (Gardner, 2001). The most obvious multiple intelligences that the IWB can address are the spatial, linguistic, and bodily kinesthetic. According to Gardner (1989) visual-spatial intelligence is characterized by the ability to perceive the spatial world accurately. The large visual display of the IWB with the vast array of colors and shapes make this tool conducive to delivering highly visual instruction. This has translated into some success with the IWB in delivering instruction to visual learners. Visual learners may be motivated by the capacity of the IWB to high quality visual images, which helps to satisfy the expectations of students who are accustomed to visual stimuli (Richardson, 2002). Further, students have also recognized the ability of the IWB to present visually stimulating images and simulations that promote their learning. In a study of student views concerning learning with an IWB Wall, Higgins, and Smith (2005) found that students ranked the visual nature of the IWB high on the list of their of learning advantages of the IWB along with: (a) facilitation, (b) use of different software, (c) initiation of learning, and (d) use of games. The interactivity of the IWB is cited by many as the overall most important feature of the tool for sustained engagement and learning (BECTA, 2003; Smith, Higgins, Wall, & Miller, 2005). This is partially because the interactivity meets the needs of bodily-kinesthetic learners, by allowing them to physically interact with the board (Beeland, 2002; Bell, 2002). The IWB has the unique ability to address the learning needs of a diverse group of learners, but the major attraction to the IWB is the ability to engage students through physical interaction with the IWB.

The interactive features of the IWB are the primary tools teachers can use to create engaging learning activities for students. These physical interactions are the key to maximizing the functionality of the IWB. Some of the physical interactions that can take place with an interactive whiteboard are: (a) drag and drop, (b) hide and reveal, (c) highlighting, and (d) movement/animation (Glover, Miller, Averis, & Door, 2007). Drag and drop is a classification, sequencing, grouping, or matching technique that requires the user the drag an object to the correct position. Hide and reveal is another technique that allows information to be revealed as it is fully conceptualized. One example could be revealing the position of a graph after the student has plotted several points. Highlighting this an annotation tool used to add more emphasis during instruction. Movement and animation are typically used to simulate an activity or procedure for students to view or manipulate to a designate outcome. All of these types of interaction allow immediate feedback to students, which is a major benefit for student learning and lesson pacing. However, if the interactivity of the IWB is not utilized the tool may reinforce teacher-centered rather learner-centered instruction (Levy, 2002). For example, Kennewell, Tanner, Jones, and Beauchamp (2008) assert that the invention of the IWB could be seen as a step backwards, because it can give new impetus to teacher-centered approaches (p. 71). All of the previously mentioned benefits of the IWB are associated with student learning and lesson delivery. Yet, the IWB also has several practical benefits for teachers beyond lesson delivery.

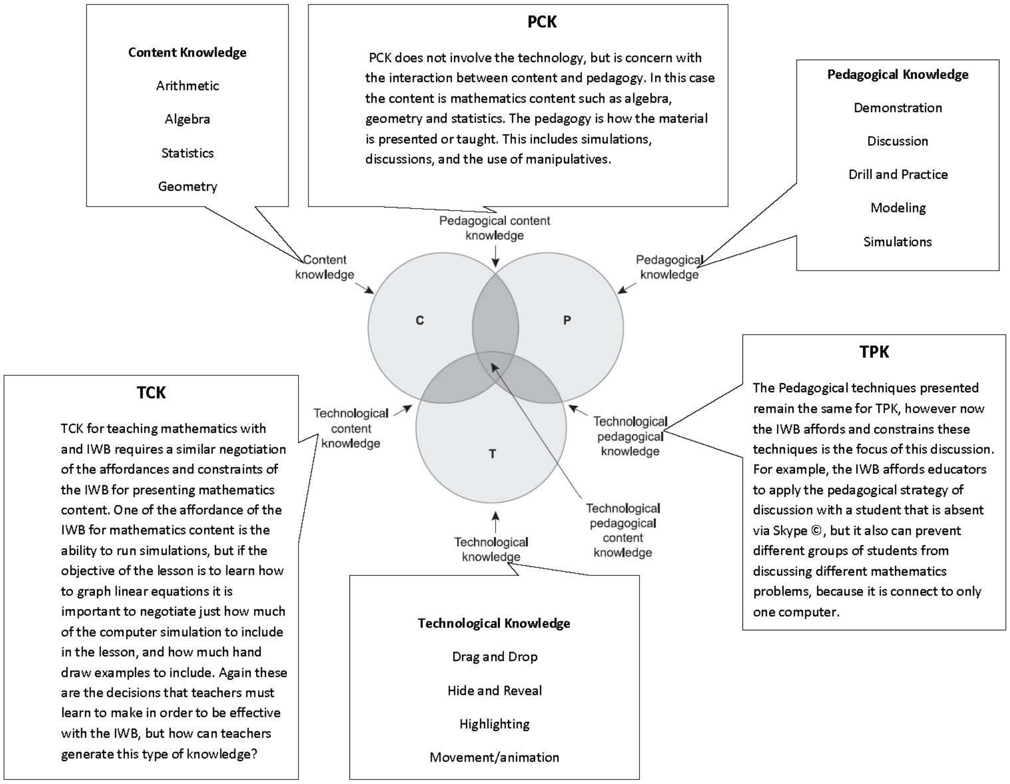
The benefits of the IWB such as centrality, interactivity, and material recycling are major affordances of the IWB for mathematics instruction, however there is little quantifiable evidence to substantiate the claim that the IWB is the sole contributor to student engagement and achievement (Smith, Higgins, Wall, & Miller, 2005). The IWB is not a technology cure all, and will not foster fundamental changes in pedagogy in and of itself (Smith, Hardman, & Higgins, 2006). The maximization of the benefits of the IWB involves the exploitation of these, as well as, other affordances of the tool, but this cannot be realized without a commitment to professional development (Armstrong et al., 2005). Therefore the remainder of this section is devoted to establishing a model for professional development for teaching mathematics with the interactive whiteboard.

Comprehensive Model for Training Teachers to Teach Mathematics with an IWB

Teaching mathematics with an IWB requires teachers to maximize the intersection between mathematics content, pedagogy, and the IWB technology, this can be difficult because the major problem seen with using the IWB in the classroom is not the skill of use, but developing pedagogical understanding (Miller & Glover, 2006). Yet, in cooperative settings teachers can achieve pedagogical advances with the IWB (Cogill, 2003). These types of instructional interactions concern TCK, TPK, PCK, and overall TPACK. Because the IWB has its own unique features, and capabilities it is important to examine how the IWB’s functionality affords and constrains mathematic content and pedagogy. The interaction between mathematics content, pedagogy and IWB technology are virtually infinite depending on teacher competence, confidence, and beliefs in relation to the subject they are teaching (Holmes, 2009). A model of the interactions between IWB technological knowledge and mathematics content and pedagogy is presented in Figure 2 to help explain these interactions.

The primary components of this model are the mathematics content, which is middle grades content such as arithmetic presented in Figure 2. This general content knowledge is then combined with five general pedagological activities present in model under pedagogy knowledge. Finally the four primary methods to use interactivity with the IWB are listed under the technological knowledge area of the model. Although there are many more technical skills that teachers can use with the IWB, the four presented in the model are the most essential to teaching mathematics with an IWB in an interactive fashion, thus they were the focus in the model. The remaining elements of the model PCK, TCK, and TPK briefly explain how the different types of knowledge afford and constrain one another. These interaction are the key to successful utilization of the IWB within the TPACK framework.

Figure 2. The intersections of PCK, TPK and TCK for teaching mathematics with the IWB



PCK

PCK does not involve the technology, but is concern with the interaction between content and pedagogy. In this case the content is mathematics content such as algebra, geometry and statistics. The pedagogy is how the material is presented or taught. This includes simulations, discussions, and the use of manipulatives.

TPK

The Pedagogical techniques presented remain the same for TPK, however now the IWB affords and constrains these techniques is the focus of this discussion. For example, the IWB affords educators to apply the pedagogical strategy of discussion with a student that is absent via Skype ©, but it also can prevent different groups of students from discussing different mathematics problems, because it is connect to only one computer.

TCK

TCK for teaching mathematics with and IWB requires a similar negotiation of the affordances and constraints of the IWB for presenting mathematics content. One of the affordance of the IWB for mathematics content is the ability to run simulations, but if the objective of the lesson is to learn how to graph linear equations it is important to negotiate just how much of the computer simulation to include in the lesson, and how much hand draw examples to include. Again these are the decisions that teachers must learn to make in order to be effective with the IWB, but how can teachers generate this type of knowledge?

Professional Development and Teaching Mathematics with the IWB

The support of researchers is important for professional development activities using IWBs (Campbell & Kent, 2010). The Knowledge Broker model is one researcher developed professional development model that can be used to support the instructional and technical needs of teachers integrating technology. Because teachers need consistent training and feedback to establish good TPACK for teaching mathematics with an IWB, the Knowledge Broker is very important in managing the progression of teacher’s use of the IWB. The knowledge broker is responsible for (a) researching the current best practices for the IWB, (b) creating exemplars of how to utilize the IWB, (c) providing just in time assistance when necessary, and (d) helping teachers progress accordingly. The progression of each teacher from novice to independent IWB user is described below.

The progression of new IWB users to higher levels of proficiency essentially the same, but described in the literature in two different manners. The first group of researchers suggested that teachers typically progress through three stages of IWB use. Betcher and Lee (2009) describe the three stages as: (a) doing old things in Old ways (b) Doing old things, but in new ways, and (c) Doing new things, in ways, while Miller, Glover and Averis (2004) describes the stages as: (a) supported didactic, (b) Interactive, and (c) enhanced Interactive. During the first phase of both progressions the IWB is used in the same manner as the traditional white/chalk board is used in the classroom. The teachers writes examples on the board, uses primarily word documents, does not take advantage of any of the interactivity of the board, nor does the teacher save any of the materials. During the second phase the teacher begins to take advantage of some of the affordances of the IWB. The teacher begins to use the flipchart instead of word, discovers the gallery, and lesson are now being saved for later use. The final stage is where the teacher begins to exploit the affordances of the IWB. Here the teacher begins to explore multimedia, using the built software as well as other packages, and records and saves all materials for future use. Once a teacher reaches the final stage he/she is able to use the IWB to create materials and deliver instruction that utilizes all of the features of the IWB in the mathematics classroom.

Summary

In this chapter research on IWB technology was synthesized across the mathematics classroom. The first section of this chapter described the influence of educational policy on technology use in the mathematics classroom. It was noted that educational policy regards the use of technology in the mathematics classroom as vitally important for present and subsequent student success. Many of the benefits of technology integration in the mathematics classroom were presented in this chapter. These benefits included: (a) development dynamic connections, (b) utilization of sophisticated tools, (c) creation resource rich-mathematics communities, (d) construction of new design tools, and (e) digital tools for exploring complexity. This chapter also reviewed the past and current research on professional development and described how professional development has changed to address the new technological needs of the classroom. Finally, this chapter concluded with an overview of affordances of the IWB, and a description of a proposed model to train teachers to teach mathematics with IBW technology.

CHAPTER III

METHODOLOGY

The purpose of this study was to examine the effects of a TPACK professional development for using IWBs on teacher self-efficacy about mathematics teaching with IWB technology. To fulfill this purpose mathematics teachers in a Central Texas School district underwent three weeks of professional development to assist them with teaching mathematics with the IWB.

This study answered the following questions:

1. What is the influence of a three-week Teaming to Teach with Technology (TTT) Interactive whiteboard professional development on middle school mathematics teacher TPACK in an urban middle school?
2. Does student achievement increase when Teaming to Teach with Technology (TTT) professional development for using the IWB is introduced to mathematics teachers in an urban middle school?
3. Is urban middle school student mathematics achievement differentiated across race after teachers receive three-weeks of IWB Teaming to Teach with Technology (TTT) professional development?
4. What are the barriers to integrating the IWB in mathematics classrooms in an urban school?

To better ascertain the research context for this study it is important to understand when and where this study was conducted.

Research Context

This study was conducted in four Central Texas Middle Schools that serve a mixed population of Hispanic, African American, and White students in descending population rank order. A convenience sample of teachers, who were given IWBs as part of the school districts technology initiative were the sample for this study. The teachers taught grade levels that ranged from 6th through 8th grade, and all of the teachers taught mathematics.

Variables

The effects of the professional development were assessed through teacher Technological Pedagogical Content Knowledge (TPACK), as well as, student mathematics Texas Assessment of Knowledge and Skills (TAKS) results. The independent variable in this study was the professional development. The professional development was the independent variable because all of the teachers received IWB's as part of a district wide technology initiative, and thus had prior use of the IWB before the training. Because all of the teachers used the IWB before the study the professional development not the IWB is the variable that is manipulated. The dependent variables in this study were teacher TPACK and student mathematics achievement. As a result of the professional development teachers should gain a better understanding of TPACK and its components. Student achievement is thus indirectly dependent on the professional development. The control variables in this study were the content of the professional development, the geographic location of the professional development, the target grade levels (Middle School), and the duration of the professional development.

Research Participants

The participants in this study were seven female and one male mathematics teachers. The representation of the participants in this study is as follows: 75% White, 12.5% African American, and 12.5% Hispanic. The schools in this study are referred to as school A and B. School A's teachers taught only 6th, 7th and 8th grade mathematics. Data were collected from five teachers from school A and four from school B. As mentioned earlier the teachers in this study taught 6th, 7th and 8th grade, specifically two teachers taught 6th grade, four teachers taught 7th grade, and four teachers taught 8th grade. Table 1 below outlines the classroom profile for all teachers in the study.

Research Design

A quasi-experimental design was utilized in this quantitative study. By definition a quasi-experiment is "an experiment were units are not assigned to conditions randomly" (Shadish, Cook, and Campbell, 2002, p. 12). As part of this design, teachers were not randomly assigned to particular students or vice -versa, nor were specific types of IWB technologies randomly or purposely assigned. The assignments were made through administrator selection and not by self-selection. Therefore, teachers did not decide which students they wanted to teach the decision were predetermined. An artifact of the district was that two different IWB tools were in use at the district and therefore, were represented in this study. The teachers in this study used two IWB devices. The majority of the teachers used the Mimio©, while a small minority of this teachers utilized the **INTERWRITE**®BOARD. No specific generalization about the suitability or usability of one over the other was made.

Table 1

School A& B Participant Course/Classroom Descriptive Data

Teacher	Number of Students by Grade level	Course Title
	School A	
Teacher 1	N = 41, 7th grade	7th grade math
Teacher 2	N = 101, 7th grade	7th grade math/GT/Pre-AP
Teacher 3	N= 97, 8th grade	8th grade Math/TAKS math
Teacher 4	N = 96, 8th grade	8th grade math/Algebra
	School B	
Teacher 5	N = 108, 6th grade	6th grade math
Teacher 6	N = 19, 6th grade N = 118, 7th grade N = 27, 8th grade	6th grade math/7th grade math/8th grade mathematics
Teacher 7	N = 115, 7th grade	7th grade math
Teacher 8	N = 107, 8th grade	8th grade mathematics

Data Collection

Data were collected using a one-group within participant's pretest-posttest design procedure to assess the effects of the professional development on teacher TPACK and IWB use in the classroom. The major threats to validity for this design are maturation and history (Shadish, Cook, and Campbell, 2002). To minimize the maturation threat and the history threat the tie between the pretest and posttest was kept as short as possible. Schools A and B both received three weeks of professional development with the IWB. Two weeks in the fall of 2009 and one week in the spring of 2010. The pretest data were collected before the initial week of professional development, and prior to the last day of the professional development. The section that follows describes how the three weeks of professional development was delivered.

Professional Development Delivery Model

Plair (2008) created the Knowledge Broker model to address educators craving just-in-time support to address issues that arise from the rapidly evolving nature of technology. The Knowledge Broker has several distinct roles in professional development. The first is Harbinger of innovation, which entails researching new advances on technology by participating in continuing education programs and conferences (Plair, 2008). The Knowledge Broker then applies this new knowledge to assist teachers in the classroom. The second role is master of strategies and techniques, which involves having expert content specific technology knowledge and suggestions for classroom applications of technology. The third role is teaching artists, which involves integrating the content knowledge and in this case development of TPACK, for use in the classroom. As a teaching artist the knowledge broker is expected to exhibit the best practices with the IWB. The knowledge broker is also on call for just-in-time tech assistance. This was facilitated through the exchange of cell-phone as well as email correspondence between the researcher and the participants. Each campuses technology specialist was also available for general technical issues. The final role of the knowledge broker is catalyst for change and unity, which involves maintaining technology standards and adoption of new strategies (Plair). This model was used to meet the needs of the teachers in this study during each week of the professional development. You need a concluding sentence here.

Each daily session was held during teacher conference or off periods, and included no more than three teachers per session. This allowed for extended periods of one on one exposure and training. The first week of training focused on incorporating each teacher's current teaching materials into IWB. These materials included PowerPoint slides or other electronic data that the teacher used for instruction. This part of the training could also be described as "Doing old things in old ways". During this week, mathematics content and pedagogy were the primary concern during the professional development, thus the teachers were asked to use previous lesson materials that could be critiqued and improved to address appropriate content and pedagogical concerns. The second week of training took place two weeks after the first with each schools training sessions beginning on a Monday and Ending on a Friday. This week was dedicated to doing old things but in new ways. This was achieved by introducing teachers to how the IWB technology could enhance their mathematics content presentation and classroom pedagogy. The objective of this week was to have the teachers move their traditional lesson into the IWB software environment.

During the second week training session teachers were introduced to many of the tools available with the IWB software. In particular the mathematics portion of the individual IWB's software galleries was explored. These galleries contain simulations, lesson templates, and links to external files that are compatible with the IWB. Three folders were the focus of this activity: (a) the fraction folder, (b) the probability and statistic folder and (c) the measurement folder in the gallery were explored. The six interactive techniques described by Miller, Glover, and Averis (2004) as drag and drop; hide and reveal; color, shading and highlighting; matching equivalent items; movement or animation; and immediate feedback were introduced and explained in detailed. The culmination of this week was each teachers presentation of his/her lesson created in the IWB flipchart and recorded using the record feature of the particular software. Each lesson had to incorporate at least two of the six common interactivity techniques and at least one of the researcher provided flash applications.

The third and final week was designed to have the teachers do new things in new ways. During this week teachers were expected to exercise their TPACK for teaching mathematics with and IWB to create a engaging mathematics lesson. All new lessons were the focus of the week. Teachers were given the option to make the lessons tailored for TAKS or just for everyday classroom use. The restrictions for this week were that the lesson had to maximize the interactivity of the IWB by including: all six types of interactivity, flash applications from the web, at least one other software application (i.e. Word®, Excel®, GeoGebra®, etc.), one video snippet, and finally the lesson had to be recorded in real-time during an actual class session. During this week and throughout each of the previous weeks the researcher was present as a Knowledge Broker to provide just in time assistance, as well as, instructional and pedagogical support as needed.

Instrumentation

The data was collected on one survey, a modified version of survey of pre-service teacher knowledge of teaching and technology. The pre-service teacher TPACK survey contains items from various content domains and has been shown to be considerable reliable for several different samples. The survey of pre-service teacher knowledge of teaching and technology has an internal reliability that ranges from .80 to .92 (Schmidt, Baran, Thompson, Koehler, Shin, & Mishra, 2009). The individual reliability for mathematics, Pedagogy knowledge, Pedagogical Content Knowledge, Technological Content Knowledge, Technological Pedagogical Knowledge, and Technological Pedagogical Content Knowledge are .85, .84, .85, .86, .80, and .92, respectively. The survey items appear in Appendix A. The items were Likert scaled and scored from 1 Strongly Disagree to 5 Strongly Agree.

Instrumentation Reliability and Validity

The data analysis for this study was conducted in two phases. The first phase was designed to address the reliability of the survey data collected. First all teacher data was coded and placed into SPSS. A reliability analysis was conducted to assess the reliability of the responses to the survey overall and in each subscale. Because the modify version of survey of pre-service teacher knowledge of teaching and technology contains 28 items, designed to measure 8 subscales, which assess 8 dimensions of TPACK a confirmatory factor analysis was conducted. The confirmatory factor analysis was to be conducted through structural equation modeling. The proposed fit indices were χ^2, the root mean square error of approximation (RMSEA), and the confirmative fit index

(CFI). Multiple fits indices were proposed because each index provides different information about the model fit (Brown, 2006). The χ^2 is a measure of the exact fit of the proposed model, while the RMSEA is a measure of model fit that adjust for model parsimony, and the CFI is an incremental fit index. Each proposed model index is subject to its own statistical sensitivity. The χ^2 is sensitive to sample size and the RMSEA is sensitive to the number of model parameters. Two models were proposed and the model parameters were estimated using maximum likelihood estimation. The first model was completely uncorrelated while the second model correlated several of the latent variables. A principal component factor analysis with varimax rotation was conducted to examine the construct validity of each knowledge domain on the subscale. The Bartlett's test of sphericity was conducted to whether or not the correlation matrix was an identity matrix. The null hypothesis is that the correlation is an identity matrix, thus the it was important that the null hypothesis was rejected. The Kaiser-Gutman rule was used to select the factors in this analysis. The Kaiser-Gutman rule states that factors with Eigen values greater than one should be accepted, thus this is the rule that was applied. The questionable items from each TPACK domain subscale were reviewed and eliminated if they did not support the construct or if they reduce the internal reliability. The results of the reliability analysis and PCA analysis for each item are presented in the tables appendix A.

Technological knowledge was the first knowledge domain examined. One factor, accounting for 64.7% of the total variance was presented using 4 items of the teacher self-reported knowledge of technology knowledge. The Cronbach's alpha for technological knowledge was .810. The second knowledge domain was pedagogical knowledge. Here, one factor was identified to account for 85.1 of the total variance. For this knowledge domain 3 items were present and a Cronbach's alpha of .911 was observed. The third knowledge domain was content knowledge. The analysis for this domain produced one factor that accounted for 82.7 of the total variance with 2 items. The Cronbach's alpha for the content domain was .774. The next knowledge domain was the technological content knowledge domain. Once again one factor accounted for 67.0 present of the total variance across 2 items. The Cronbach alpha for this domain was 484. The next domain was pedagogical content knowledge. This domain had once factor account for 92.1 of the overall variance across 2 items and a Cronbach's alpha of .889. The next domain technological pedagogical content knowledge had one factor account for 87.8 of the total variance in 2 items. The Cronbach's alpha for the technological pedagogical content knowledge domain was .696. The final knowledge domain was Technological pedagogical content knowledge. This domain had one factor account for 65.3 of the total variance. The Cronbach's alpha for technological pedagogical content knowledge was .694. The Cronbach's alpha for the instrument was α(instrument) = .798.

Data Analysis Procedures

The second phase of the data analysis was to assess the statistical significant differences between teacher TPACK pretest and posttest score, as well as student assessment data before and after the teacher received the professional development. To test for statistically significant differences between the pretest and posttest scores on the survey data a paired *t*-test was proposed. The paired t test was chosen because the same teachers were the participants of the pretest and posttest in this study. Thus, the teachers initial TPACK for using IWB's was compared to their TPACK after the treatment.

The student achievement data for research questions two and three was analyzed by means of propensity score matching, which was proposed by Rosenbaum and Rubin (1983) for estimating the effects of non-randomized experiments. Because was a non-random experiment it is important that the treatment and control group are similar across a multitude of characteristics, in order to isolate the treatment effects in this study. The teachers received the treatment in this study so the students were matched according by teacher first and then on several other characteristics. To achieve appropriate matching it is important to have as many characteristics as possible to adequately match the treatment and control groups. These characteristics are multidimensional and can include: race, socio-economic background, prior-achievement, as well as numerous other factors. Rosenbaum (1998) proposed to reduce these characteristics into a single scalar, or summary score known as the propensity score. The propensity scores for this study match treatment and control groups on the following student characteristics: ethnicity, gender, school, grade, gifted status, ESL services, and LEP services. The scores were calculated by binary logistic regression and saved to the initial SPSS file. Binary logistic regression was use to determine the propensity scores. Logistic regression was chosen over other methods such as discriminant analysis for two reasons. The first reason is because logistic regression is a robust method that is not subject to a plethora of assumptions. Further logistic regression allows the user to utilized both categorical as well as scale variables. The logistic regression covariates were ethnicity, gender, and grade level. These covariates were used to determine the student's probability of being in the treatment group, thus treatment was the dependent variable. The overall fit of the binary logistic model was assessed by the Hosmer and Lemeshow chi-square test of goodness of fit. The achievement data was compared using a 2X4 *ANOVA*. Mean differences in student achievement between the treatment and control group were assessed, as well as, means differences between the following groups: Black, Hispanic, Asian, and White.

Summary

This chapter describes the methodology used in this study. The participants in this study came from a Central Texas school district, and all participants were teachers in Middle schools in the district. The methodology presented in this section was designed to answer the three research questions presented in this study. 1. What is the influence of professional development on teacher TPACK? 2. Does student achievement increase when TPACK for using IWB is introduced to mathematics teachers? 3. Is student achievement differentiated across race? Two analysis were use to answer this questions. The first is the *t test* and the second is the multi-way *ANOVA*. The results of these tests are presented in the chapter that follows.

CHAPTER IV

RESULTS

The data collected from the professional development and surveys administered in this study answered the following questions:

1. What is the influence of a three-week Teaming to Teach with Technology (TTT) Interactive whiteboard professional development on middle school mathematics teacher TPACK in an urban middle school?
2. Does student achievement increase when Teaming to Teach with Technology (TTT) professional development for using the IWB is introduced to mathematics teachers in an urban middle school?
3. Is urban middle school student mathematics achievement differentiated across race after teachers receive three-weeks of IWB Teaming to Teach with Technology (TTT) professional development?
4. What are the barriers to integrating the IWB in mathematics classrooms in an urban school?

However before the test could be performed the construct validity and item reliability were examined. Confirmatory factor analysis was initially suggested as the means on investigating the construct validity of the survey, but the small sample size prevent the established of construct validity by means of item analysis techniques. The content validity however is a product of the definitions and descriptions of TPACK present in the current literature that utilized similar survey items. The descriptive statistics at the item and construct level are reported in the in Appendix B.

Effect Size and Confidence Interval Results

Because the number of participants in this study is substantially small, it is both impractical and analytically unsound to conduct statistical significance testing. Thus, effect sizes and confidence intervals were used to evaluate the teacher pretest and posttest results. Effect sizes provide a magnitude of effect that addresses the practical importance of the results (LeCroy & Krysik, 2007). By examining mean difference effect sizes, the influence of the professional development on teacher self-efficacy was assessed for practical significance. One rationale for reporting effect sizes is that measures of effect size can be compared across studies (Vacha-Haase, Nilsson, Reetz, Lance, & Thompson, 2000). Accordingly, the reasonableness of the results was examined by comparing the results from this study to two similar studies. 95 % confidence intervals about the mean difference effect size were also calculated.

In order to create a fair comparison across effect sizes several stipulations for inclusion were employed. First all of the studies were quasi-experimental studies where the dependent variable was teacher Technological Pedagogical Content Knowledge (TPACK). The studies included in this analysis involved either pre-service or in- service teachers that received technology professional development to improve TPACK. Second the studies needed to use a one-group pre-post test design. The literature search did not yield any true experimental designs. Further, because the these studies were selected for comparison purposes the design specifications were held constant in the selection of studies to include in the analysis. Third, the studies needed to use the *survey of teacher knowledge to teach with technology* an instrument that measures teacher technology instruction self-efficacy to examine teacher TPACK. Because the *survey of teacher knowledge to teach with technology* was first published in 2009 by default all studies included in the confidence interval analysis were published between 2009 and 2011. Based on these stipulations eight studies were met all of the inclusion criteria and were thus used in the confidence interval analysis.

Standardized mean difference effect sizes were chosen for this study. According to Lipsey and Wilson (2001) the standardized mean effect size contrast groups on their mean scores on a dependent variable not operationalized the same across studies. This assumption was made because not all of the studies used the same survey to measure teacher self-efficacy. All of the effect sizes were calculated from samples less than 20, thus they were corrected using the Hedges small sample bias correction formula (Hedges, 1981). Appendix B contains a table that list the teacher mean difference effect sizes by factor, and standard deviations.

Along with strong evidence of affect from the effect size calculations, confidence intervals were selected to analyze the survey results from this study for two primary reasons. The sample size for this study was considerably small, thus NHSST would not yield statistical significant results. Unfortunately, the conclusion typically associated with non-statistically significant results is that the effect is not real (Cumming & Finch, 2007), which is not the case in the present study. Secondly, because all confidence intervals report both (a) point estimates and (b) characterized how mush confidence can be vested in a given point estimates (Zientek, Yetkiner, & Thompson, 2010, p. 425) comparing point and interval estimates to other studies examines precision and quality of the results of this study across other studies.

Confidence intervals were computed and compared across several studies in the recent literature that utilized the survey of pre-service teacher knowledge of teaching and technology to assess the results of professional development on TPACK. Studies were selected based primarily on the independent and dependent variables and the manner in which they were manipulated and measured. All of the studies need to use some form of professional development to manipulate teacher TPACK. Also, all studies selected measured teacher TPACK used the same or a modified form of the survey used in the present study; the survey of pre-service teacher knowledge of teaching and technology.

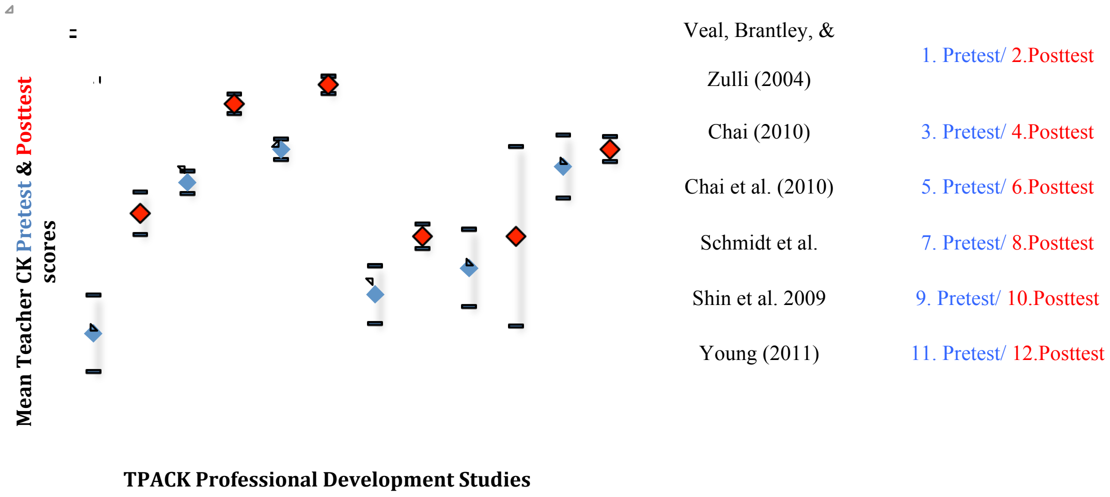
The survey of pre-service teacher knowledge teaching and technology was developed and analyzed for validation by Matthew Koehler and Punya Mishra, two of major champions of TPACK (Schmidt, Thompson, Koehler, Mishra, & Shin, 2009). Further, this is the survey that was slightly modified for this study, and thus is the most appropriate metric for comparison across current professional development literature that used the same survey. The survey was designed on a 5 point Likert scale, and scores ranged from 1 for “Strongly Disagree” all the way up to 5 for “Strongly Agree”. The mean of each construct is calculated to form the score for that particular construct, thus the seven items that measure Technical Knowledge (TK) are averaged to determine the overall score for TK.

To compare the various confidence intervals across studies, the conventional 95% confidence level was chosen because it is the most commonly found level in the literature. Fortunately, all of the studies selected provided all the information pertinent to the confidence interval calculations, thus no other information was needed. The Stock option in Microsoft Excel was used to create the graphical displays of the confidence intervals for all seven constructs of TPACK. The point and interval estimates for the individual means for the present study were compared to the other studies, first across all of the TPACK constructs. The purpose of this comparison was twofold. First this allows the one to assess the precision of the point and interval estimates in comparison to other studies. Secondly, the reasonableness of the mean point estimates can be assessed across studies. Both of these assessments are performed by means of visual inspection and are to a certain degree subjective, but for the most part guided by sound theory.

The precision of the point estimate hinges upon the margin of error associated with the point estimate. According to Cumming and Finch (2007) the CI will be a range centered on M, and extending a distance w on either side of M, where w (for width) is called the *margin of error* (p. 170). Therefore, individual Confidence intervals a smaller *margin of error* or width are more precise. The *margin of error* is based on the standard error and is a function of the SD and n, as seen in the formula for standard error $SE = SD/\sqrt{n}$ (Cumming & Finch). The confidence intervals that have narrowed bands or widths are more precise and tend to have a large sample size or smaller SD. Because the sample size in the present study is relatively small, it is a reasonable assumption that the confidence intervals will be wider, and therefore less precise. However, by comparing the point and interval estimates across other studies one can better ascertain the relative precision of the estimates in this study.

The first construct investigated was Content Knowledge (CK). The pretest and posttest point and interval estimates were slightly different, the pretest width was slight wider than the posttest width. Neither the pretest nor the posttest confidence interval for the present studies was the widest or least precise. The overall mean scores for content knowledge for this population range between roughly 4 and 5, based on confidence interval overlap and clustering of point estimates in Figure 3.

Figure 3. Confidence intervals for mean Content Knowledge (CK) scores in professional development studies using the survey of pre-service teacher knowledge of teaching and technology pre and post test pairs.



The scores for the technology knowledge construct for the present study were relatively precise compared to the other studies, but it is worth mentioning that the level of precision (assessed by narrowness of confidence intervals) was much higher for this construct. The confidence intervals for the Technical Knowledge (TK) construct are cluster between two separate ranges of scores as seen in Figure 4 below. The first is between 4.5 and 5 and the second is between 3.5 and 4, furthermore do to the narrow confidence intervals across studies there is little overlap between the two clusters of scores. The pedagogy knowledge (PK) construct had the narrowest confidence intervals across all of the constructs investigated. The scores in Figure 5 are either slightly above or slightly below 4, thus the best range for scores on PK would be between the range of 3.8 to 4.2.

Figure 4. Confidence intervals for mean Technical Knowledge (TK) scores in professional development studies using the survey of pre-service teacher knowledge of teaching and technology pre and posttest pairs.

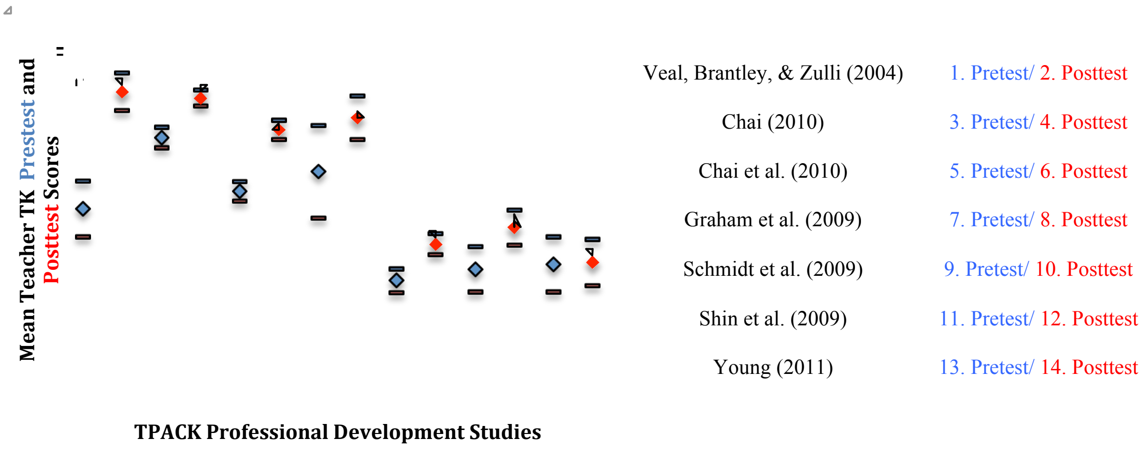
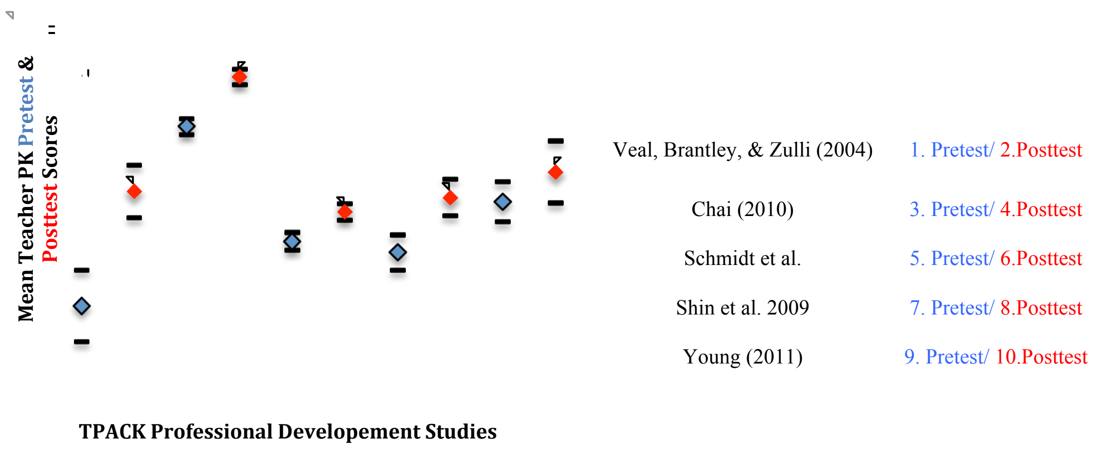


Figure 5. Confidence intervals for mean Pedagogical Knowledge (PK) scores in professional development studies using the survey of pre-service teacher knowledge of teaching and technology pre and posttest pairs.



The remaining constructs Technological Pedagogical Knowledge (TPK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), and Technological Pedagogical Content Knowledge (TPACK) and their respective point and interval estimates are presented in Figures 6 through 9. The confidence intervals for TPK are relatively similar to the previous confidence intervals for the other bands and the scores fall in a range of approximately 3.5 to 4.5. However, the remaining constructs PCK, TCK, and TPACK have confidence interval with bands much wider than the bands presented in the previous figures. The point estimates and intervals for the present study remain reasonably precise as well as the appropriate range of all of the scores for the each of the aforementioned constructs.

Figure 6. Confidence intervals for mean Technological Pedagogical Knowledge (TPK) scores in professional development studies using the survey of pre-service teacher knowledge of teaching and technology pre and posttest pairs.

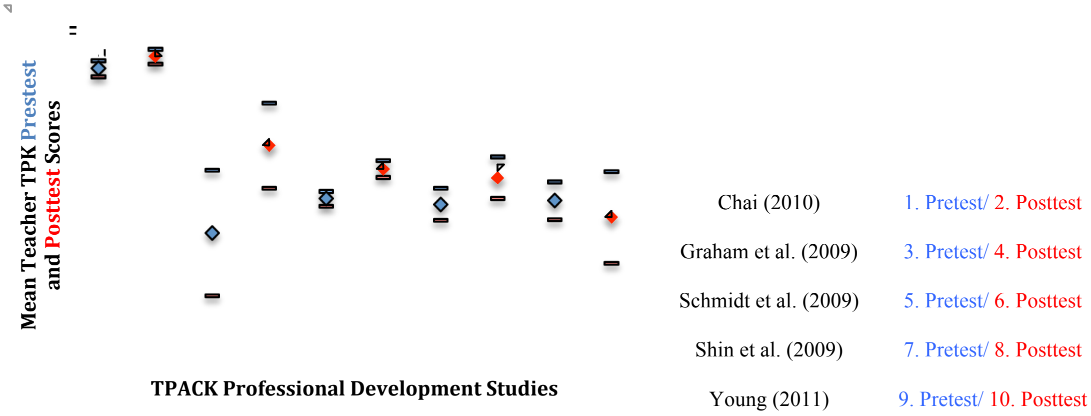


Figure 7. Confidence intervals for mean Pedagogical Content Knowledge (PCK) scores in professional development studies using the survey of pre-service teacher knowledge of teaching and technology pre and posttest pairs.

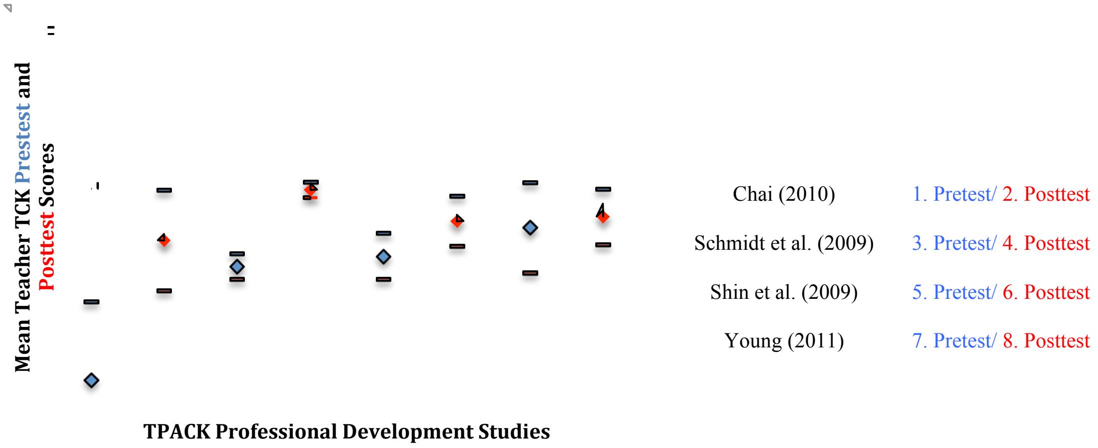


Figure 8. Confidence intervals for mean Technological Content Knowledge (TCK) scores in professional development studies using the survey of pre-service teacher knowledge of teaching and technology pre and posttest pairs.

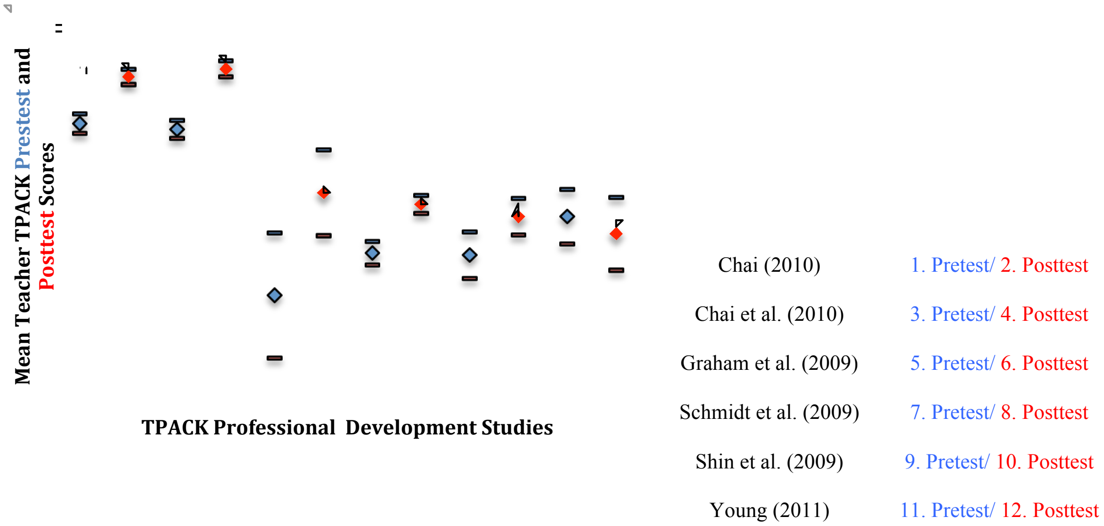
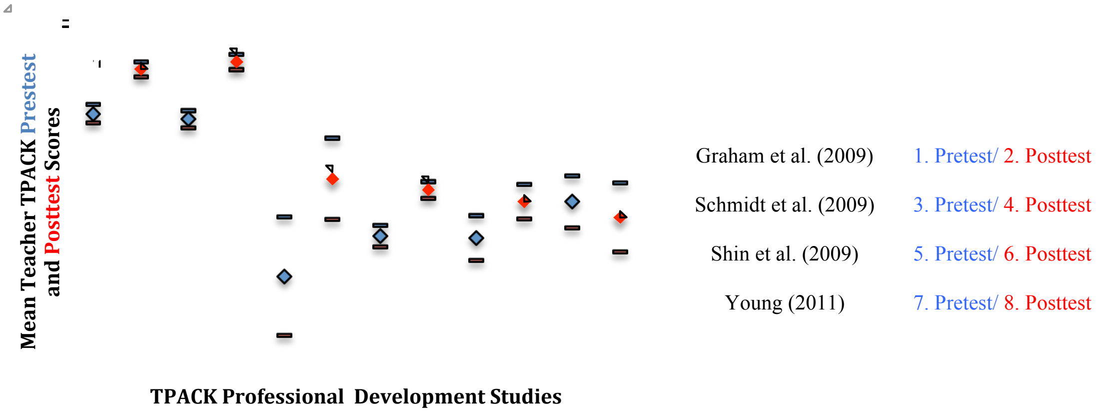


Figure 9. Confidence intervals for mean Technological Pedagogical Content Knowledge (TPACK) scores in professional development studies using the survey of pre-service teacher knowledge of teaching and technology pre and posttest pairs.



Cumming and Finch (2007) present five rules for visual interpretation of confidence intervals. Rule number five concerns paired data and how to best represent and interpret confidence intervals for such data. Cummings and Finch (2007) suggest that for paired data:

"Focus on and interpret the mean of the differences and the CI on this mean. Noting whether the CI on the mean of the differences captures 0 is a test of the null hypothesis of no difference between the means" (p. 177). Thus, along with the previous assessments of precision and reasonability, the confidence intervals of the mean differences are also examined for intersections whether the bands capture zero. Confidence intervals for mean differences in pretest and posttest scores are presented in Figures 10-16.

The overall confidence intervals for the mean differences in CK are much wider than the intervals for the means of the construct. The confidence interval for this study is not the widest, but it is the third widest in Figure 10. Thus, it is the third least precise of the estimates presented in the figure. The range in mean differences in CK after professional development is approximately between 0.3 and 0.6. The Confidence intervals for PK in Figure 11 were similar to those for CK, and the range of mean difference in PK were between approximately 0.1 and 0.5. Confidence intervals for TK were very wide compared to CK and TK confidence intervals, indicating that they were less precise estimates across all studies compared to the previous estimates. The point estimate for TK for the present study was much lower than the other point estimates and the confidence interval intersected zero, indicating that there was little to no difference in the TK means. The overall range of mean difference in TK for the professional development studies was roughly between 0.4 and 0.7. The remaining mean differences are from constructs that measure the interrelated knowledge teachers received from professional development.

Figure 10. Confidence intervals for Content Knowledge (CK) mean differences in professional development studies using the survey of pre-service teacher knowledge of teaching and technology

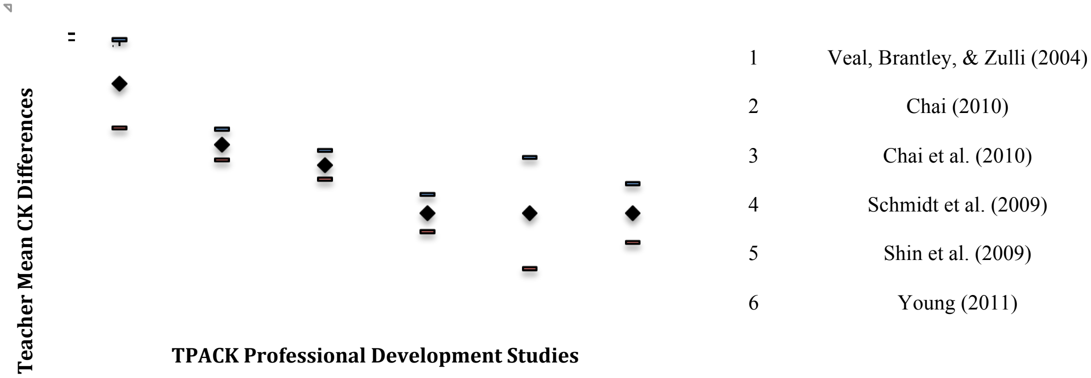


Figure 11. Confidence intervals for Pedagogical Knowledge (PK) mean differences in professional development studies using the survey of pre-service teacher knowledge of teaching and technology

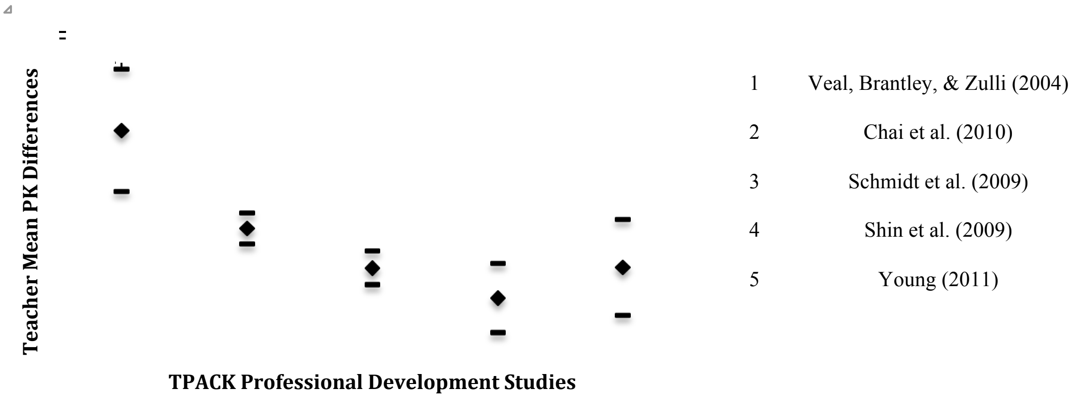
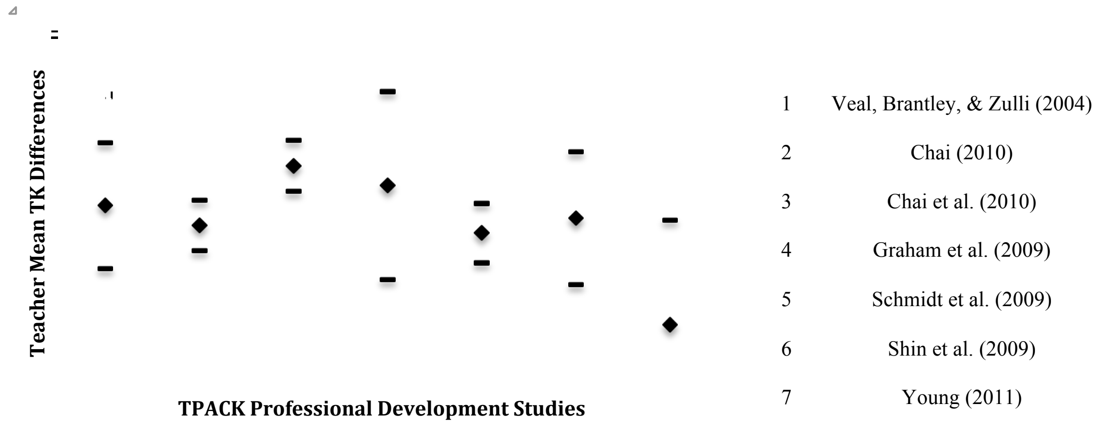


Figure 12. Confidence intervals for Technical Knowledge (TK) mean differences in professional development studies using the survey of pre-service teacher knowledge of teaching and technology



Figures 13 -16 concern mean differences in PCK, TPK, TCK and TPACK. Aside from one study that had a negative mean difference the overall mean difference for PCK were almost identical point estimates, and the intervals were more narrow that the confidence intervals for previous mean differences. Likewise the range in mean differences for PCK is between 0.3 and 0.4 as seen in Figure 14. The range of mean differences in TPK was from approximately 0.1 to 0.35. The point estimate for the present study was below zero, which indicated that the mean score in TPK after the professional development was less than before. The point estimate for mean difference in TCK is outside to the range for the mean difference point estimates in Figure 16, which is between .4 and .9. Further, the confidence interval for he corresponding point estimate subsumes zero, thus indicating that there is relatively little difference between the pretest and posttest scores on TCK. The mean differences in TPACK measured by the pre-service teacher survey of teaching and technology ranged from .4 to .7. The point estimate for the present study was below zero, but subsumed zero, thus there was little difference between the pretest and posttest scores on TPACK.

Figure 13. Confidence intervals for Pedagogical Content Knowledge (PCK) mean differences in professional development studies using the survey of pre-service teacher knowledge of teaching and technology

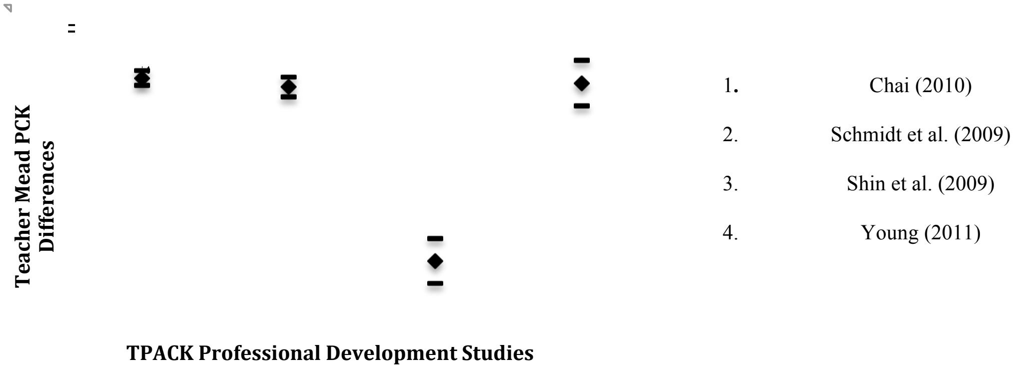


Figure 14. Confidence intervals for Technological Pedagogical Knowledge (TPK) mean differences in professional development studies using the survey of pre-service teacher knowledge of teaching and technology

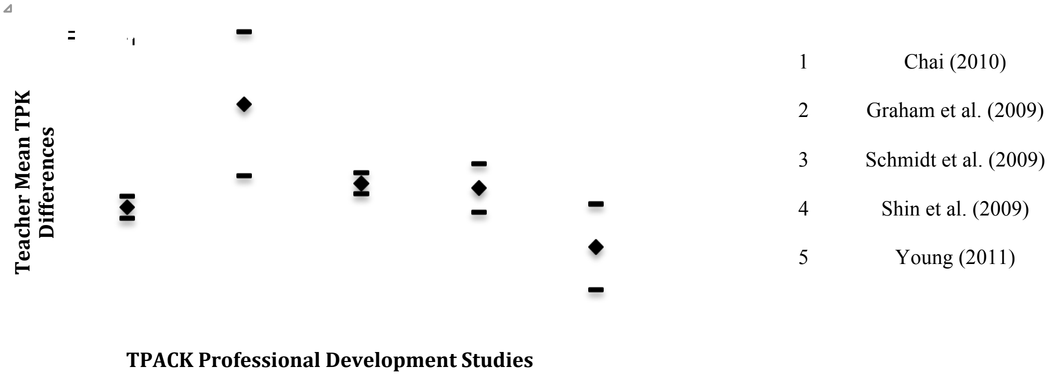


Figure 15. Confidence intervals for Technological Content Knowledge (TCK) mean differences in professional development studies using the survey of pre-service teacher knowledge of teaching and technology

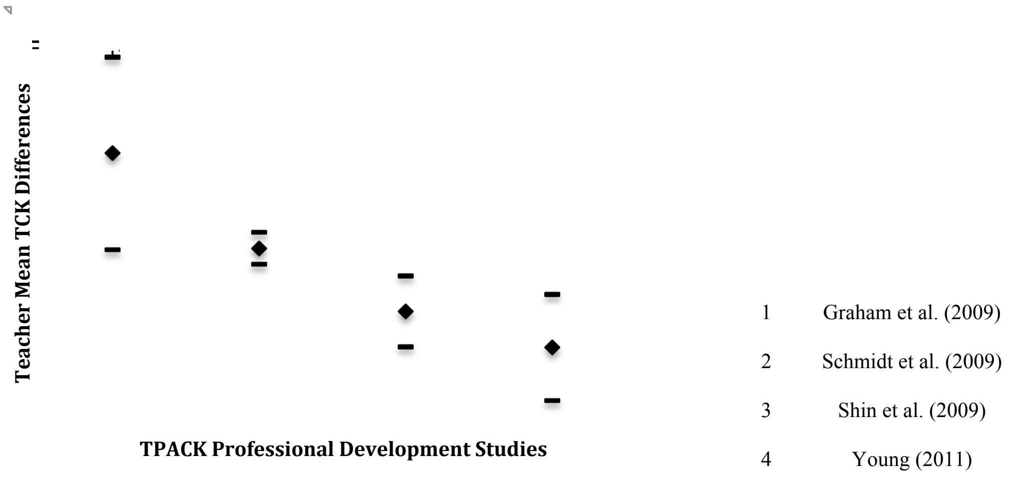
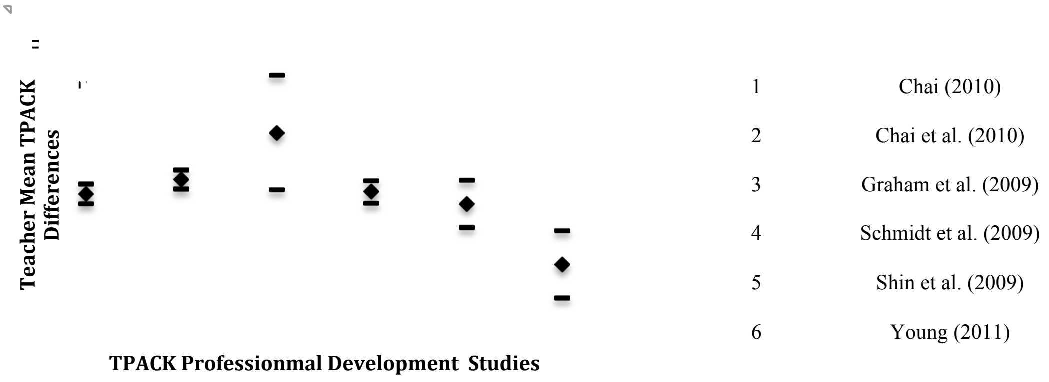


Figure 16. Confidence intervals for Technological Pedagogical Content Knowledge (TPACK) mean differences in professional development studies using the survey of pre-service teacher knowledge of teaching and technology



In summary, the mean point and interval estimates were considerably more precise than initially assumed given the relatively small sample size compared to the other studies. The point estimates were all with in the same range as the majority of the point estimates from other studies and exhibited similar patterns as the other studies in a given construct. The mean difference confidence intervals for the current study were similar in some constructs and very different in other constructs compared to other studies. The confidence intervals subsumed zero in TK, TCK, TPK and TPACK suggesting that there was little to no difference before and after the treatment for these constructs.

Propensity Score Matching Results

Mathematics TAKS scores on the 7th and 8th grade mathematics TAKS for 716 of the participants' students were compared to a sample of 856 students that formed the control group. Tables 2-4 shows the differences between the participants' students and the control sample before matching. The students in the control sample have a higher mean mathematics TAKS, however the students differ on a number of important covariates as shown in Tables 2, 3, and 4. These participants' students and the control sample are different on a number of covariates, but notable differences are in the percentages of students receiving GT, ESL and LEP services.

Table 2

Gender, ESL, LEP and Gifted Characteristics before Matching

Characteristics		Treatment	Non-treatment
Gender	Male	50.2%	52.0%
GT	Yes	15.9%	14.4%
ESL	Yes	12.3%	9.2%
LEP	Yes	11.2%	9.5%

*Before matching Treatment *N* = 716 & Control *N* = 856

Table 3

*Grade Level of Unmatched Group*s

Grade	Treatment	Non-treatment
6th	14.4%	15.9%
7th	41.0%	38.8%
8th	44.6 %	45.3%

*Before matching Treatment *N* = 716 & Control *N* = 856

Table 4

Ethnicities of Students in Unmatched Groups

Grade	Treatment	Non-treatment
Asian	0.3%	0.2%
Black	29.0%	26.8%
Hispanic	59.3 %	63.4%
White	11.4%	9.5%

*Before matching Treatment $N = 716$ & Control $N = 856$

Binary logistic regression was use to determine the propensity scores. Logistic regression was chosen over other methods such as discriminant analysis for two reasons. The first reason is because logistic regression is a robust method that is not subject to a plethora of assumptions. Further logistic regression allows the user to utilized both categorical as well as scale variables. The logistic regression covariates were race/ethnicity, gender, and grade level. Race and ethnicity are similar, but not the same. Ethnicity is essentially *Hispanic or Latino,* a person of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin, regardless of race (NCES, n.d.). While race encompasses five categorizations including: (a) American Indian or Alaska Native, (b) Asian, (c) Black or African American, (d) Native Hawaiian or Other Pacific Islander, and (e) White (NCES). Since Black and African American are both used by the National Center for Educational Statistics and the Department of Education

Black was chosen to represent this group of students exclusively. These covariates were used to determine the student's probability of being in the treatment group, thus treatment was the dependent variable. The overall fit of the binary logistic model was assessed by the Hosmer and Lemeshow chi-square test of goodness of fit. The output of the test is presented in Table 5. The test was non-significant at the .05 level, thus it was concluded that the model fits the data adequately.

Table 5

Results of the Hosmer Lemeshow Chi-square Test of Goodness of Fit

Chi-Square	df	Sig
3.658	8	.887

The propensity scores were saved to the original spss files and a SPSS macro was applied to match the teacher's students to a pool of control students (Dattalo, 2010, p. 145). The aforementioned macro matched the treatment students to control students based on propensity scores generated by the logistic regression. The macro returned 500 matches, but only with differences less than .0001 were considered. Thus, 109 matches were selected to be included in the analysis. After matching on propensity scores the groups are remarkably more similar, Tables 6 through 8 represent the post-matched student scores. The initial experimental group contained 716 participants and the initial control group 856 participants and N = 1572. After the propensity score matching procedure both the experimental and control groups contain 109 participants, which yielded a new *N* = 218.

Table 6

Gender, ESL, LEP and Gifted Characteristics after Matching

Characteristics		Treatment	Non-treatment
Gender	Male	54.1%	54.1%
GT	Yes	34.4%	34.4%
ESL	Yes	2.8%	2.8%
LEP	Yes	2.8%	2.8%

* After Matching Treatment *N* = 109 & Control *N* = 109

Table 7

Grade Level of Matched Groups

Grade	Treatment	Non-treatment
6th	0%	0%
7th	20.2%	20.2%
8th	79. 8%	79.8%

* After Matching Treatment *N* = 109 & Control *N* = 109

Table 8

Ethnicities of Students in Unmatched Groups

Ethnicity	Treatment	Non-treatment
Asian	0%	0%
Black	31.2%	31.8%
Hispanic	53.2 %	53.2%
White	15.6%	15.4%

* After Matching Treatment *N* = 109 & Control *N* = 109

Two answer questions two and three of the study a Multi-way *ANOVA* was completed with treatment group and ethnicity as the factors and student mathematics TAKS scores as the dependent variables.

Results of Multi-way *ANOVA*

Prior to conducting the *ANOVA* the normality and equality of variances assumptions were assessed. The student's scores for this study were slightly positively skewed with a coefficient of skewness of .258. A Shapiro-Wilk test was applied to test for normality of the data. The results were statistically significant thus it was concluded that the student data was not normal. However after examining the histogram for the student data and the Q-Q plot the deviations from normal were not considered to be extreme. Figures 17 and 18 are a histogram and Q-Q plot of the student's scores respectively.

The results of the multi-way *ANOVA* were non-statistically significant for the treatment main effect $F(1,206) = 0.019$, MSE = 17.757, $p = 0.892$. The ethnicity main effect was statistically significant $F(2,206) = 12.399$, MSE = 17.757, $p < .000$. The Gender main effect was statistically significant $F(1, 206) = 4.435$, MSE = 17.757, $p < 0.05$. The interaction effects were all non statistically significant.. The results of the Levene's Test were statistically significant, thus the Games-Howell Post hoc test was applied to identify the differences amongst the different ethnicities. The results of the Games-Howell post hoc test indicated that there were statistically significant differences between all three Ethnic groups in the study. Partial Eta –squared effect sizes were calculated for the all main and interaction effects (see Table 9).

Figure 17. Histogram of student raw scores and minor kurtosis

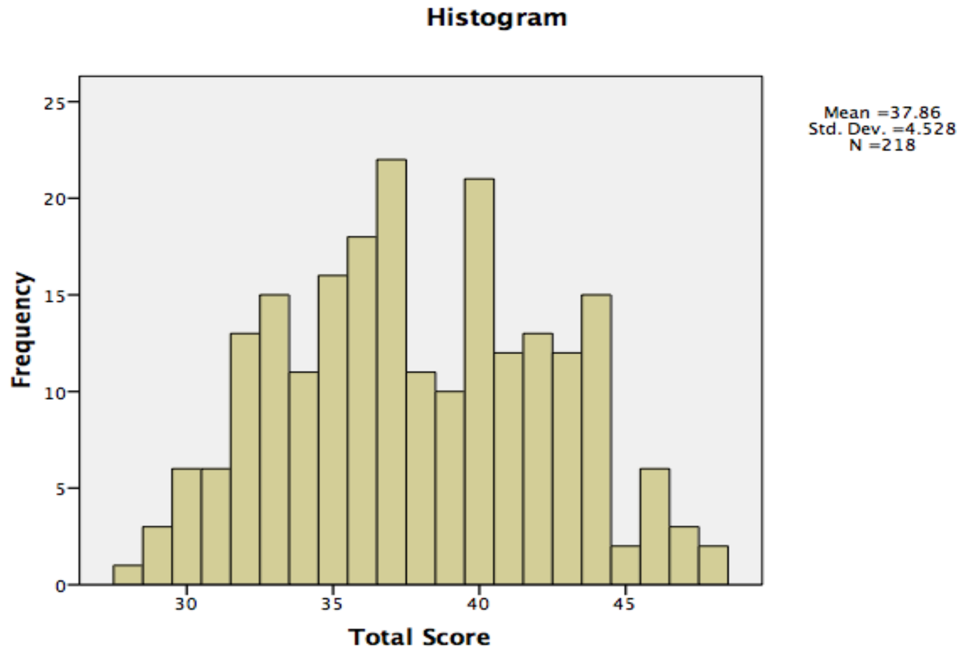
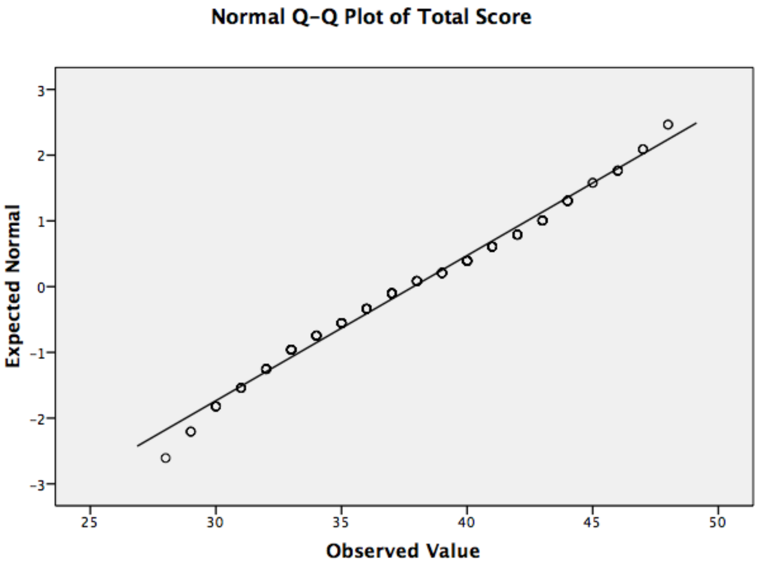


Figure 18. Q-Q Plot of student raw score data



Other notable difference include, strong increases in mathematics TAKS scores despite a lack of statistical significant difference. One of the major concerns of NCLB and the school district where this study took place was difference in achievement across the different ethnic groups. Whether differences existed after the study was important because closing the achievement gap is a significant issue in the nation in general and for this school district in particular. A closer look at the differences in achievement is thus warranted. Below are Tables 10 and 11. These tables show the differences in achievement among and between each ethnic group. The tables show that each group's score increased except for the Hispanic students whose score actually decreased slightly. Gaps in achievement were also reduced for all groups except the Hispanic students.

Table 9

Effect Sizes of Main and Interaction Effects

Factor	η
Treatment	0.000
Gender	0.021
Ethnicity	0.107
Treatment x Gender	0.000
Treatment x Ethnicity	0.029
Gender x Ethnicity	0.002

Table 10

Achievement Differences across Ethnicities

Ethnicity	N	Mean	SD	Mean	SD	Cohen's *d*
Black	68	34.76	3.562	36.82	4.616	-0.50
Hispanic	116	38.53	4.390	38.21	4.192	0.075
White	34	40.73	4.723	38.50	3.989	0.51

Table 11

Gaps in Achievement after Treatment

Group	Mean 1	Mean 2	Δ
White/Black	40.73	34.76	5.97
White/Hispanic	40.73	38.53	2.36
Hispanic/Black	38.53	34.76	3.77

The treatment mean scores were higher than the control group mathematics TAKS scores as seen in in Appendix C. Gender differences however tell a different story. Female students in the treatment group had a slight decrease in scores, where as male students had an increase in scores (see Figure in Appendix C). The treatment effects were also differentiated across ethnicity. White students had the increase in scores followed by Hispanic students. Black students in the treatment group did not improve, but scored lower than the control group (see Figure in Appendix C).

The final question in this study asked: What are the barriers to integrating the IWB in mathematics classrooms in an urban school? The results of this study identified several barriers to integrating IWB technology in mathematics classrooms in an urban school. Butler and Sellbom (2002) identified a list of barriers to technology integration for teaching and learning: a) reliability, b) time to learn the technology, c) knowing how to use the technology, d) concern that technology might not be critical for learning, and e) perception of inadequate institutional support. The teachers in this study were presented with each of the aforementioned barriers to technology integration.

The technology reliability was a major issue. The computer in both scores used older processors that struggled to run the software needed to used the IWB. Furthermore, because the IWB purchased by the district was portable many of the teachers simply could easily remove the IWB between sessions and avoid having to use it. Further, the time to learn the technology was hinder by the many overarching responsibilities of the teachers in both schools. Each professional development session took place during the teacher's teaming period, but many of the teachers were responsible for hall duty, mentorship programs, or consistently needed to solve a major campus crisis between different groups of students. All of these activities affected the time teachers had to learn the technology.

Although the purpose this study was to help integrate the IWB into classroom instruction, many of the teachers did not know how to use the IWB despite having the tool at their disposal for over a year. This is compounded because the tool is mobile and can be hidden away in a closet. Many teachers expressed an attitude that the IWB was not necessary for student learning. Especially given the curricular demands of high-stakes testing, teachers expressed genuine concerns that the time that working with the IWB could be spent improve other instructional practices. Finally, many teachers believed that they lack institutional support to use the IWB successfully. The major concern was the lack of better computers to run the software, which were promised by the schools administration. Other concerns were that the new curriculum was difficult to implement along side the IWB technology. All together this represent valid barriers to the integration of the IWB in middle school mathematics classrooms that must be addressed to improve implementation.

Summary

This section presented the results of the professional development and the affects of this treatment in teacher TPACK and student achievement. Teacher TPACK was increases across almost all constructs measured by the survey. This is apparent in the positive mean effect sizes observed in almost all constructs in this study. Furthermore, the comparison of the present study pretest and posttest mean scores on each TPACK construct to other published studies that used the same survey indicated that the results from this study are in the same range as the results in other studies. The treatment main effect was not statistically significant, but the ethnicity and gender main effects were statistically significant. Several barriers to integrating IWBs into urban middle schools were identified to include: a) reliability, b) time to learn the technology, c) knowing how to use the technology, d) concern that technology might not be critical for learning, and e) perception of inadequate institutional support. These barriers varied in the prevalence between the two campuses in this study, but a detailed discussion of these and aforementioned results is provided in the discussion section.

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

The goal of this study was to address the need for training to teach mathematics with the IWB. To address this goal a 3-week professional development intervention was completed. The affect of the professional development on the teachers Technological Pedagogical Content Knowledge (TPACK) was assessed by a pretest posttest design. Besides address the need for effectively professional development this study also sought to examine how student achievement was affected by teachers new knowledge and skills. Four research questions were posed to address the goals of this research study.

Discussion of Results

The first question in this study was: What is the influence of a three-week Teaming to Teach with Technology (TTT) Interactive whiteboard professional development on middle school mathematics teacher TPACK in an urban middle school? The smaller the sample size the less likely the results will be statistically significant. Thus mean difference effect sizes were calculated to examine the influence of the professional development on teacher TPACK self-efficacy. However, the effect sizes of the test are a direct indication of the effectiveness of the treatment on teacher TPACK. Thus, the professional development effectively increased teacher Technical Knowledge (TK), Content Knowledge (CK), Pedagogical Knowledge (PK), Technological Content Knowledge (TCK), and Pedagogical Content Knowledge (PCK). The effect sizes for these constructs range from small to quite large, and were all positive. According to these results, after the professional development teachers were more confident in their technical ability with the IWB. Examples of this technical ability include: (a) uploading office documents, (b) creating notebook documents, (c) interacting with the IWB, and (d) utilizing multimedia. The survey results also indicated an increase in CK, PK and PCK, which is essential for good mathematics teaching and learning. Although mathematics content and pedagogy was not the primary focus of this study, the activities all requires teachers to examine their thoughts about content and pedagogy in relation to the IWB, which lead to subsequent increases in their self-reported abilities in these areas. The results also suggest that teacher ability to fuse their newly acquired technical skills with the mathematics content was increased. Based on the results of this survey teachers have a better understanding of how technology can afford and constrain mathematics content and likewise how mathematics content maximize the features of the IWB or minimize their effects. The professional development was however ineffective in two areas Technological Pedagogical Knowledge (TPK) and TPACK.

The effect sizes for TPK and TPACK were -0.342 and -0.362 respectively. These negative effect sizes suggest that the treatment decreased teacher TPK and TPACK. The similar magnitude of the effect sizes is interesting and may suggest that the treatment effect was similar and that the constructs are similarly evaluated. Thus, a detailed discussion of each possibility is warranted. The interrelationship between technology and pedagogy is not as apparent as the connections between technology and mathematics content. For example, mathematics concepts are heavily laden with representations, these include: (a) equations, (b) graphs, (c) manipulatives, and other visual representations. All of which can be represented in a multitude of ways through the utilization of various features of the IWB. However, mathematics pedagogy is less apparently connected to IWB technology. For instance, one type of mathematics pedagogy is teacher's ability to diagnose and treat student misconceptions. The connection between this type of pedagogy and the IWB is related to the lesson planning and delivery of the mathematics content on the IWB. Thus, as teacher develops TPK he or she designs lesson content that presents situations that enable he or she to examine student misconceptions. Likewise, the columniation; TPACK is highly dependent of TPK to be effective. Therefore it is not surprising that teacher TPK and TPACK did not increase due to TPK influence on TPACK. As mentioned in the methodology section an examination of construct validity was not feasible do the small nature of the sample size, but a qualitative examination of the TPK and TPACK items is presented in the section that follows.

The items for TPK and TPACK respectively were extracted and placed in Appendix F. Upon further examination the TPK and TPACK items although different in quantity ask very similar in content and structure. The TPK scale contains two items, while the TPACK scale contains 5 items as seen in Appendix C. All of the items except one begin with "I can…." and then conclude with and action related to teaching and learning approaches or activities with technology. The similar nature of these items may contribute to the similarity of the overall responses for both constructs. In regards to the first research question for this study the effects of the professional development on teacher TPACK suggest that the professional development increased teach TK, PK, PCK, and TCK. However, the professional development did not increase teacher TPACK and TPK.

Review of Multi-way ANOVA Results

The second concern of this study was whether or not student achievement would increase as a result of the professional development experiences of the teachers. Specifically this study asked: Does student achievement increase when Teaming to Teach with Technology (TTT) professional development for using the IWB is introduced to mathematics teachers in an urban middle school? Overall student achievement did increase as a result of the professional development that the teachers received. The results were not statistically significant, but an increase in scores although small was observed in the study. The partial eta-squared effect size for the treatment was 0.00, this suggest that the treatment was not directly affecting the student scores. This is not surprising because the treatment/professional development was an indirect treatment. Therefore, the effects are typically seen in a longitudinal fashion. The third research question concerned differences across ethnicities. Upon review of these results, a literature search was conducted to examine the current literatures perspective on teacher professional development and student achievement. According to Desimone (2009) the effects of teacher professional development on student achievement occur in an indirect manner. Further, Desimone, Porter, Garet, Yoon, & Birman (2002) suggest that a four year window is the minimum amount of time needed to begin to notice any differences in student achievement that stem from teacher professional development. The premise for these conclusions are the nature of teacher professional development and the time needed for teachers to practice, perfect, and begin to implement the new skills in the classroom. Thus, because the professional development model use in the present study did not last the minimum four years it is not unlikely that the differences in student achievement scores were not statistically significant.

Question three asked: Is urban middle school student mathematics achievement differentiated across race after teachers receive three-weeks of IWB Teaming to Teach with Technology (TTT) professional development? The results of the multi-way *ANOVA* suggest that achievement was differentiated across ethnicities. The ethnicity main effect was a statistically significant result present in the multi-way *ANOVA* results. The partial η^2 for the ethnicity main effect was 0.107. Thus, approximately 10.7% of the variance in student performance can be attributed to ethnicity.

The results of the *ANOVA* suggest that the differences in student performance do exist across the different student groups represented in this study. This is important because as teachers acquire new teaching skills gaps in performance should be come smaller. All of the student groups expected the Hispanic student scores increased, although the increases were not statistically significant. This is notable because this represents good progress although small. The Hispanic scores however are still higher than the Black scores, but the decrease in Hispanic scores in an unexpected result nonetheless.

Several barriers to the integration of IWBs emerged in this study. The five barriers identified as the most obstructive are discussed in detail. The reliability of the technology was a major barrier at the onset of the professional development. Software as well as hardware reliability issues were present at both of the professional development locations. Initially many of the computers at both locations were unable to support the required IWB software packages; furthermore many of the IWB's were locked away in remote locations across the campus. Another technical barrier was that the Mimio ©, is a portable IWB device, is affixed to the traditional dry-erase board, while the **INTERWRITE**®BOARD is a standalone device mounted in the classroom. Because the **INTERWRITE**®BOARD is mounted, teachers that had these in their classrooms may have felt more obligated to incorporate these technologies, as opposed to those who have a portable IWB like the Mimio©, which can be removed and placed in a storage closet rather easily. These issues made it difficult to begin the professional development on the initial day, which cut into the scheduled professional development activities.

Time to learn the technology was also an issue in this study. Because the sessions were held during the teacher conference and teaming periods, many of the teacher responsibilities overlapped with the professional development activities. One of the major limitations of this study was time on task. Because each of the middle schools operates as its own entity with different schedules and procedures the professional development activities took place during separate one-week intervals at each school. Each session was limited to 45 minutes, but because the sessions took place during school operating hours minor "crisis" delayed teacher attendance from time to time. For example, the first 10 to 15 min of many of the sessions was spent waiting on the teachers to return from hall duty. The technical nuances of the IWB devices was not the focus of the professional development, but upon arrival at each school it became apparent that despite the districts technology initiative and investment, many of the teachers had yet to incorporate the IWB into their daily instruction.

Thus, knowing how to use the technology was a major barrier in this study. This was evident in the number of classrooms, where the IWB was not present before the initiation of the training. Out of all the classrooms represented in this study only 3 teachers had the IWB visible in the classroom, and of these three two were classrooms where the IWB was mounted but not functional. Thus, the first day of the first week of the professional development was dedicated to locating and installing the IWB in each participant's classroom. After each IWB was installed, it was imperative that each teacher received an up to date installation of the appropriate software for the particular IWB. This was also at times cumbersome, because many of the computers that were available for the teachers to use with the IWB were running out of date operating systems that prevented the software from installing properly.

Unfortunately, upon returning for the second session little had changed from the first in regards to teachers using the IWB actively in their classrooms. One observation that was interesting during this second session was that many of the teachers that had undergraduate teaching assistants or student teachers actively using the IWB in the classroom. The participant however was not the using the tool exclusively; the participant and the student teacher however were teaming teaching with the IWB in the classroom.

The teacher expressed their lack of concern for the ability of technology to influence learning, by simply not utilizing the tools available. Although this study consisted of a convenience sample of teachers that received IWB's as part of a district wide initiative many of the teachers did not use these technology until the first day of the training which was almost two years since the teachers received the IWBs. Many of the teachers expressed their disdain for technology and felt as though it was a good thing for the students, but not a necessary for student achievement. Teachers expressed similar feelings about the district curriculum and the lack of support in the implementation of technology, which coincides with the barrier of: perception of inadequate institutional support. This may account for the TPK and TPACK results seen in this study. The district curriculum was scripted and thus teachers could not deviate from the materials and activities, thus addressing TPK and TPACK was very difficult to implement in the professional development. This is because TPK and TPACK require the teacher to create materials, but the teachers in this study were unable to create any of their materials. All of these factors are systemic factors that may impede the integration of technology in these schools.

Conclusion

The purpose of this study was to examine the effects of a TPACK professional development for using IWBs on mathematics teaching and learning with IWB technology. The section of he study examines the results of this study in relation to the review of literature and prior studies.

This study addressed the following questions:

1. What is the influence of a three-week Teaming to Teach with Technology (TTT) Interactive whiteboard professional development on middle school mathematics teacher TPACK in an urban middle school?
2. Does student achievement increase when Teaming to Teach with Technology (TTT) professional development for using the IWB is introduced to mathematics teachers in an urban middle school?
3. Is urban middle school student mathematics achievement differentiated across race after teachers receive three-weeks of IWB Teaming to Teach with Technology (TTT) professional development?
4. What are the barriers to integrating the IWB in mathematics classrooms in an urban school?

In regards to the first question in this study the influence of the professional development was positive for all the constructs except TPK and general TPACK. This can be attributed to many systemic as well as design considerations. The systemic considerations are the many barriers to technology integration. Aside from the systemic factors presented in the previous section, several design considerations are worth investigating at this point. The primary design concern is the manner in which the professional development content was delivered. Much of the initial professional development time focused on the establishment of technological competence with the IWB. The goal was to move the teachers through the three stages described by Betcher and Lee. These stages were: (a) doing old things in Old ways (b) doing old things, but in new ways, and (c) doing new things new in ways (Betcher & Lee, 2009). In order to guide teachers through these stages the model presented by Miller, Glover and Averis, was used as a progress benchmark (Miller, Glover, & Averis, 2005). Thus as teachers began to move from the supported didactic phase to the Interactive, and finally enhanced Interactive phase their progress was marked accordingly in the three initial stages. This system of tracking teacher progress was an excellent tool to add a level of accountability to the professional development, but this measure of accountability does not directly reflect the TPACK skills measured in the survey. This disconnect could be partially responsible for the lack of consisting in the results from the survey analysis. In the future a more holistic approach to teacher accountability and feedback should be employed. Niess et al.(2009) suggest that a mathematics teacher TPACK standards and development model is necessary for conducting effective TPACK focused professional development. According to Niess et al. mathematics teachers progress though five stages. The stages are as follows:

> 1. *Recognizing* (knowledge), where teachers are able to use the technology and recognize the alignment of the technology with mathematics content yet do not integrate the technology in teaching and learning of mathematics.
>
> 2. *Accepting* (persuasion), where teachers form a favorable or unfavorable attitude toward teaching and learning mathematics with an appropriate technology.
>
> 3. *Adapting* (decision), where teachers engage in activities that lead to a choice to adopt or reject teaching and learning mathematics with an appropriate technology.
>
> 4. *Exploring* (implementation), where teachers actively integrate teaching and learning of mathematics with an appropriate technology.
>
> 5. *Advancing* (confirmation), where teachers evaluate the results of the decision to integrate teaching and learning mathematics with an appropriate technology. (p. 9)

If these new stages were implemented into the current delivery format used for this study then a better sense of teacher TPACK could be achieved as the professional development activities progressed. The second research question investigated the effects of the professional development on student achievement.

The effects of the professional development on student achievement were less than ideal, however because the treatment was indirect this is to be expected initially. The results of the 2X4 *ANOVA* did not reflect any statistically significant differences in the treatment main effect. Furthermore, the η^2 effect size for treatment main effect was 0.00. These result are not ideal, however they are not unusual. In a recent study of teacher use IWBs in various content areas researchers found that 23% of the teachers that did not use the IWB had better student performance on a standardized test (Marzano & Haystead, 2009). Video of data from the study suggested that many of the teachers that used the IWB to teach did not employ good teaching practices with the technology. Four common instructional pitfalls were identified: (a) using built in voting devices, but not utilizing the data collected, (b) lack of lesson pacing and organization, (c) using too many visuals, and (d) paying too much attention to the reinforcement features (Marzano, 2009). Many of the teachers in the present study may have committed the same pitfalls mentioned here, but because teacher video data was not collected it is impossible to be certain. Thus, collecting video or other observation data of teachers using the IWB should be implemented in the future to assure that the teachers are using the IWB in the classroom and that teacher use is appropriate.

Recommendations

The purpose of this study is to examine the effects of a professional development for using the IWB on teacher TPACK and student achievement. To fulfill this purpose, mathematics teachers in a Central Texas School district underwent three weeks of professional development to assist them with teaching mathematics with the IWB. The results of this study provide teachers, administrators, researchers, and leaders of professional development valuable insight into the design and implementation considerations necessary for effective professional development to teach mathematics with an IWB. The results of this study suggest that professional development can increase teacher TPACK. However, the appropriate conditions for success technology integration are necessary for the professional development to be most effective. Teacher must be willing to gain the technical competence necessary to use the IWB, and administrators must provide adequate support structures to assist teachers before, during, and after the professional development to establish sustained results.

Professional development leaders need to understand how to create conditions that are necessary to equip teachers with a good technical foundation, as well as a smooth transition into a more content focused utilization of the IWB. Professional development leaders should also seek to make the best of all of the contact hours at their disposal. Because, simply providing more time does not yield any benefits unless the time is used wisely. Along with the initial duration of the professional development, time spent providing feedback and follow-up is also important to support teachers begin to implement changes in their practice. Furthermore, the duration of a professional development program is only relevant if that time is well organized, carefully structured, purposefully directed, and focused on content or pedagogy or both (Darling-Hammond, Hammerness, Grossman, Rust, & Shulman 2005; Guskey, 2009; Supovitz & Turner, 2000). This can be facilitated through teacher observation and feedback to track teacher knowledge and skill acquisition. Many of the current IWBs have built in recording features that can be used to capture three to four lessons throughout the professional development. These lessons can be used to track teacher progress in an uninhibited manner.

Researchers should use the results of this study to create new and more holistic measures of teacher TPACK. The instrument used in the current study was a self reported measure. Teacher self-report data although relatively easy to capture, can be riddled with teacher biases. For instance, teachers may not take the survey seriously and mark erroneous responses. A TPACK teacher observation instrument may serve as a better measure of the teacher initial and final progress toward gain TPACK for using the IWB.

This professional development although effective in some areas, did not effectively increase teacher knowledge across all of the measured TPACK constructs. More work is needed to modify the professional development activities to better address TPK and general TPACK knowledge. Furthermore, a more longitudinal design is necessary to fully examine the effects of the professional development on student achievement as a whole, and across ethnicities. If these adjustments are made future studies should better ascertain the influence of professional development on teacher TPACK and student achievement.

Teachers and administrators in urban middle schools should try to avoid the barriers identified in this study if they want to maximize the integration of IWBs in their school. Communication between faculty and administrators may be a means of addressing many of these barriers. However more sensitive matter such as perceptions of lack of support are better addressed through some form of mediation. The results also indicate that the effects on achievement were differentiated across different ethnicities. This data is important and requires more research to yield a better understanding of this differences and how they relate to the IWB. The hope is that the recommendation will allow other researchers, teachers, and administrators to learn from this study and improve research and practice with the IWB in middle school mathematics classrooms.

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APPENDIX A

Factor Matrix for Technology Knowledge (TK)

	Loadings	Alpha
Technology Knowledge (TK)		.810
TK1. I have had sufficient opportunities to work with different technologies.	.825	
TK4. I frequently play around the technology.	.955	
TK5. I keep up with important new technologies.	.898	
TK7. I can learn technology easily.	.435	

Factor Matrix for Content Knowledge (CK)

	Loadings	Alpha
Content Knowledge (CK)		.761
CK2. I understand mathematics well enough to employ multiple strategies.	.770	
CK3. I have the mathematics content knowledge I need to teach mathematics.	.818	
CK4. I continue to develop my understanding of mathematics.	.906	

Factor Matrix for Pedagogical Knowledge (PK)

	Loadings	Alpha
Pedagogical Knowledge (PK)		.761
PK2. I know how to organize and maintain classroom management.	.770	
PK3. I can adapt my teaching based-upon what students currently understand or do not understand.	.818	
PK4. I can use a wide range of teaching approaches in a classroom setting (collaborative learning, direct instruction, inquiry learning, problem/project based learning etc.).	.906	

Factor Matrix for Pedagogical Content Knowledge (PCK)

	Loadings	Alpha
Pedagogical Content Knowledge (TCK)		.889
PCK1. I know how to select effective teaching approaches to guide student thinking and learning in mathematics.	.960	
PCK2. I am familiar with common student understandings and misconceptions in mathematics.	.960	

Factor Matrix for Technological Content Knowledge (TCK)

	Loadings	Alpha
Technological Content Knowledge (TCK)		.484
TCK1. I can choose technologies that enhance the content for a lesson.	.818	
TCK2. I can choose technologies that enhance the content for a lesson.	.818	

Factor Matrix for Technological Pedagogical Knowledge (TPK)

	Loadings	Alpha
Technological Pedagogical Knowledge (TPK)		.821
TPK1. I can adapt the use of the technologies that I am learning about to different teaching activities.	.937	
TPK2. I can choose technologies that enhance students' learning for a lesson.	.937	

Factor Matrix for Technological Pedagogical Content Knowledge (TPACK)

	Loadings	Alpha
Technological Pedagogical Content Knowledge (TPACK)		.694
TPACK1. I can select technologies to use in my classroom that enhance what I teach, how I teach and what students learn.	.782	
TPACK3. I can teach lessons that appropriately combine mathematics, technologies and teaching approaches.	.925	
TPACK4. I can use strategies that combine content, technologies and teaching approaches in my classroom.	.702	

APPENDIX B

Item Descriptive Statistics

Pretest vs. Posttest Item Descriptive Statistics

	Pretest Results		Posttest Results		Mean Difference
	Mean	SD	Mean	SD	
TK1	3.38	.916	3.38	0.744	0.00
TK2	3.38	.518	3.38	0.744	0.00
TK3	3.25	1.061	3.25	0.886	0.125
TK4	3.38	1.061	3.12	1.246	-0.250
TK5	3.62	.744	3.38	0.916	-0.250
TK6	3.75	.707	4.12	0.835	0.375
TK7	4.12	.354	4.38	1.061	0.250
CK1	1.75	1.389	1.00	0.000	-0.750
CK2	4.50	.535	4.88	0.354	0.375
CK3	4.88	0.354	4.88	0.354	0.00
CK4	4.75	.463	4.88	0.354	.125
PK1	4.00	.000	4.50	0.535	0.500
PK2	4.25	.436	4.25	0.707	0.00
PK3	4.25	.463	4.50	0.535	0.250
PK4	4.12	.354	4.62	0.518	0.500

	Pretest Results		Posttest Results		Mean Difference
	Mean	SD	Mean	SD	
TCK1	3.62	1.061	4.12	0.354	0.500
TCK2	3.62	.744	3.38	0.744	-0.250
TPK1	3.88	.354	3.75	0.886	-0.125
TPK2	3.75	.707	4.00	0.00	-0.250
PCK1	4.25	.463	4.50	0.535	0.250
PCK2	4.25	.463	4.62	0.518	0.375
PCK3	4.00	0.00	4.38	0.744	0.375
TPACK1	3.75	.463	3.38	0.744	-0.375
TPACK2	3.75	1.035	3.88	0.835	0.125
TPACK3	4.25	.463	4.75	0.463	0.500
TPACK4	4.12	.354	4.00	0.756	-0.125
TPACK5	4.00	.535	3.25	0.535	-0.750

Mean Difference Effect Size Results

Factor	Mean Difference	SD	ES
TK	0.0357	0.9717	0.037
PK	0.3250	0.525	0.618
CK	-0.0625	0.8400	-0.074
PCK	0.2917	0.6241	0.467
TCK	0.1250	1.1475	0.109
TPK	-0.375	0.924	-0.406
TPACK	-0.042	0.751	-0.056

APPENDIX C

Excerpt TPK and TPACK Survey Items

Technological Pedagogical Knowledge (TPK)

TPK1. I can adapt the use of the technologies that I am learning about to different teaching activities.

TPK2. I can choose technologies that enhance students' learning for a lesson.

Technological Pedagogical Content Knowledge (TPACK)

TPACK1. I can select technologies to use in my classroom that enhance what I teach, how I teach and what students learn.

TPACK2. I can provide leadership in helping others to coordinate the use of content, technologies and teaching approaches at my school and/or district.

TPACK3. I can teach lessons that appropriately combine mathematics, technologies and teaching approaches.

TPACK4. I can use strategies that combine content, technologies and teaching approaches in my classroom.

TPACK5. I think critically about how to use technology in my classroom.

VITA

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