ABSTRACT

ADAMS, ELIZABETH KENT. The Relationship between Professional Development, Technology Infrastructure, and Teacher Technology Implementation. (Under the direction of Dr. Roger Mitchell.)

The Federal government has increasingly supported educational technology initiatives in schools serving low-income populations as one means of bolstering academic achievement. An underlying assumption has been that such initiatives can promote more effective and student-centered (or constructivist) instruction. However, the availability of computers and other technology-related resources in schools has not automatically meant their effective use in the classroom. Studies into the predictors of effective technology implementation in schools have suffered from small sample sizes, inadequate measurement, failure to deal with nested data structures, and the lack of an ecological view of the innovation - adoption process.

This study examined school and teacher level variables as predictors of technology implementation by teachers among North Carolina Schools serving low-income (Title I) populations. A cross-sectional, quasi-experimental design compared schools (n=11) participating in a comprehensive program to support technology use by teachers (i.e, the IMPACT Project) with a group of schools matched on size and socioeconomic variables (n=11). The intervention schools received funds and technical assistance to encourage school level changes that were presumed to enhance technology implementation. Responses from a survey of teachers (N=385) were used to construct measures of: teacher participation in educational technology related professional development; adequacy of technical infrastructure for technology use; and teacher implementation of technology. Covariates included: gender, ethnicity, number of years teaching, home computer access, and home
internet. Data were analyzed using Hierarchical Linear Modeling (HLM), an approach which accounts for the fact that teachers are nested within schools. It was expected that individual level teacher variables (such as participation in professional development and perception of adequate technical infrastructure) would have a greater association with teacher technology implementation in schools that had a culture supporting such practices (i.e., intervention or IMPACT schools) than those that did not (i.e., control schools).

As hypothesized, there was a positive relationship between participation in professional development and teachers’ reports of technology implementation. Contrary to hypotheses, this relationship was not moderated by status of the school as either an intervention or control school.

As hypothesized, there was a significant interaction between perceived technical infrastructure and teacher technology implementation. Teachers in the intervention schools (i.e., IMPACT) were more likely to be influenced by the levels of perceived technology infrastructure than were teachers in control schools. Teachers in IMPACT schools with higher levels of technical infrastructure were more likely to report higher levels of technology implementation.

The strengths of the study include strong measurement, clear description of program components in the comprehensive intervention, and use of multi-level modeling to address nested data. Limitations of the study are discussed, including selection factors in group assignment, generalizability, and the difficulty of attributing causation in cross-sectional designs.

The results demonstrate the importance of professional development as a predictor of technology implementation. The presence of cross-level effects was also demonstrated, in
that the effect of perceived technical infrastructure varied depending upon the school context (i.e., intervention vs. control schools.)
The Relationship between Professional Development, Technology Infrastructure, and Teacher Technology Implementation

by
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A thesis submitted to the Graduate Faculty of North Carolina State University in partial fulfillment of the requirements for the degree of Master of Science in Psychology

Raleigh, North Carolina
2010

APPROVED BY:

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_______________________________
Dr. Mary Wyer
DEDICATION

This thesis is dedicated to my mother, Susan Kent Adams, a woman of devotion, wisdom, and strength; my father, Richard Andrews Adams, a man of diligence, honor, and humor (GO DAWGS!); and my sister, Catherine Durand Adams, a woman of renewal, sincerity, and courage. They are my family, my companions, and my inspiration for the future.
BIOGRAPHY

Elizabeth Kent Adams was born and raised in Atlanta, Ga., where she attended Henry. W. Grady High School and Georgia State University, obtaining her B.A. in Psychology in Fall of 2003. Elizabeth entered the North Carolina State University Psychology in the Public Interest doctoral program during the Fall of 2004, in order to pursue her education in community development, evaluation, under-represented groups, public health, and organizational structure. She currently works for Research Triangle Institute (RTI) International, pursuing her interest in public health evaluation, particularly in the area of chronic disease.
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I would also like to acknowledge Dr. Mary Wyer and Dr. Denis Gray, both of whom act as constant mentors and truly embody the word researcher. Dr. Wyer was one of my first mentors in the Psychology Department, providing guidance, perspective, and genuine appreciation for research. She works as an advocate for graduate students, offers countless opportunities to engage graduate students in research, and fosters camaraderie while doing so. Dr. Gray provided substantial support for my master’s thesis, directing me toward appropriate literature, theoretical models, and insight into the practical significance and implications of findings. His straightforward and practical approach to research is a skill that I admire and hope to mirror over the course of my academic career.

Finally, I would like to acknowledge a few graduate students that provided immeasurable support. Tabitha Underwood was my neighbor, friend, and support during the entire thesis process. She and I spent hours discussing research, ideas, analyses, and literature. Thank you for always answering your door, for staying up late at night to counsel me, and for listening to the many facets of my master’s thesis. Lindsey McGowen was a true friend and confidant. Even in the most stressful days, she offered moral support, a shoulder
to cry on, and a positive outlook on life. There were moments that I truly would not have been able to get through without her and, for that and many other reasons. I am forever indebted.
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PROBLEM STATEMENT

In 2001, U.S. legislators developed The No Child Left Behind (NCLB) Act in order to address educational disparities in the public school system. Specifically, national indicators increasingly highlighted science and math educational deficits that disproportionately affect marginalized, low SES, students (U.S. Census Bureau, 2004). The educational divide is not new, a sad truth that is evident in past attempts to address academic disparities such as President-elect Lyndon B. Johnson’s Elementary and Secondary Education Act (ESEA) of 1965, which apportioned millions in federal funds to schools and education. NCLB is an attempt to readdress ongoing inequality in the United States’ education system.

In recent years, legislators and educators alike have turned toward a new means of correcting the educational divide: technology. The emphasis on technology can be found in Title I of NCLB, a funding initiative that provides technology funding to schools with a 50% low-income student population (Wong and Meyer, 1998), thereby continuing educational reform efforts to reduce the educational divide in the U.S. The National Educational Technology Plan publicly builds on recent investment in technology, stating that it will “strengthen school reform efforts… and accelerate academic progress.” (U.S Department of Education, 2006). Likewise, technology advocates cite several reasons for expanding classroom use of educational technology, arguing that the proper use of technology can effect wide-scale changes in education, such as 1.) increasing productivity through better teaching and learning and 2.) transforming teaching and learning from traditional textbook lessons to more
learner friendly, student-centered approaches and 3.) increasing student computer literacy so that students may compete in the recent highly technologically reliant work setting (Cuban, 2001).

In accord with national technology goals, legislators were successful in increasing the ratio of students to computers from 125 to 1 in 1984 to 4.4 to 1 in 2003. Likewise, in fiscal year 2000, Internet access reached 98% in public schools (Kulik, 2003) and 48 states included technology standards for students in 2004-2005. (U.S Department of Education, online 2006) Clearly, computer technology has become ubiquitous in U.S. public schools. Unfortunately, increased availability of computer technology has not always translated into effective or regular use. According to the National Center for Educational Statistics (NCES, 2000), despite the fact that 99% of public school teachers report access to computers and the Internet, a far lower percentage report regular and consistent use of computers to supplement curriculum activities. For example, only 66% of teachers reported using computers during class time.

The discrepancy between computer access and use is particularly profound in low SES areas, which contain marginalized students targeted to receive the benefits of computer-enhanced education. According to the National Center for Educational Statistics (NCES, 2000), while access to computers is ubiquitous across low and high SES schools, teachers in high minority enrollment schools and low income areas are less likely to use the educational technology available (Williams, 2000; Smerdon, Cronen, Lanahan, Anderson, Iannotti, & Angeles, 2000). This is remarkable, considering that the impetus for technology
implementation grew, in part, from the need to address low academic achievement scores plaguing low-SES schools. Given the amount of time, energy, and monies allocated toward educational technology implementation and the ensuing failure of these efforts, it has become necessary to re-examine technology implementation efforts. In particular, it is important to examine factors that increase teacher’s technology implementation, as these are the change agents in the classroom, responsible for introducing technology into the curriculum. Specifically, the following study will attempt to discern individual and organizational factors that predict technology implementation, focusing specifically on a comprehensive program, teacher self-reported technical infrastructure and teacher self-reported professional development participation.

Educational Technology Implementation

Definitions

*Educational technology* can be defined as tools or tool systems by which we transform parts of our educational environment, derived from human knowledge, to be used for educational purposes (adapted from Tornatzky & Fleischer, 1990). The prevailing view of educational technology simply is that it only encompasses computer hardware. However, educational technology may also include hardware such as projectors, laptops, leapfrogs, handheld clickers, or software such as Powerpoint®, Microsoft Office Tools, web-based interactive tools, drill-based math and science software, and countless other examples. While educational technologies represent a range of tools utilized in classrooms, the underlying purpose remains: increase student knowledge and skill.
Implementation refers to the realization or use of an innovation, process, or technology. (Rogers, 2003) Educational technology implementation is a stage within the innovation process, a model set forth by Everett Rogers (2003) to describe the means through which the use of new classroom tools (i.e. computer technology) becomes a routine, sustainable, and fully integrated aspect of teaching behavior. Klein and Sorra (1996) note:

Technology implementation is the transition period during which targeted organizational members ideally become increasingly skillful, consistent, and committed in their use of the innovation. Implementation is the critical gateway between the decision to adopt the innovation and the routine use of the innovation within an organization (p. 1057)

Their depiction of technology implementation reinforces the importance of implementation, while highlighting its’ place along a continuum of acceptance and incorporation.

The term implementation is often used synonymously with use, integration, and infusion, although it should be noted that these terms often correspond with increasing depth of use. Technology implementation not only involves in-class use with students, but also the ways in which teachers use technology to support curriculum activities. Thus, for the purposes of this study, implementation represents teacher technology use during curriculum planning, communication with stakeholders, as well as during class instruction.

Educational Technology Implementation and the Constructivist Approach

The national impetus toward technology implementation is often associated with a constructivist pedagogical approach. In the technology-enhanced classroom, computer hardware and software is a mechanism through which students may reach a higher level of
understanding or help to guide the pace of learning. A technology-enhanced curriculum requires teachers to incorporate technology ‘seamlessly’ into the lesson plan, resulting in a student-centered (constructivist) pedagogical approach to teaching. Constructivism is an epistemological framework articulated by social theorists such as Vygotsky (Wertsch, 1985), critical feminist researchers such as bell hooks (hooks, 1994) and educational researchers such as John Dewey (Dewey and Bentley, 1949) that highlights the active role students play in creating their own context. Constructivist learning theory, “proposes learners create their own understanding as they combine what they already believe to be true based on a blend of past experiences with new experiences” (Rakes, Fields, and Cox, 2006, p. 410). In the constructivist classroom, students filter information based on their previous knowledge and experiences; therefore, they are not passive recipients of knowledge, but active and information-seeking individuals. Constructivist pedagogy is an intentional teaching style that relies on student-guided discussion and student-centered activities in order set the pace of the classroom and develop higher order thinking skills.

Similarly, Baylor and Ritchie (2002) point out that there are varying instructional approaches to technology implementation and that not all approaches will produce the same outcomes or effects. Baylor and Ritchie (2002) note the distinction between technology implementation focused on learning about computers versus learning with computers (i.e. technology-enhanced curriculum). Specifically, the objective of courses about computers is to develop student’s computer knowledge and skill, such as learning to keyboard or learning
a new computer software program. Alternatively, learning with computers focuses on teachers incorporating technology to reinforce content or subject matter knowledge.

As computer software has become more advanced, many educational researchers viewed technology as a constructivist tool, a means through which classroom activities may be guided by student inquiry on the Internet or through real-time student responses using Clickers. Becker and Ravitz (1999) posit that technology provides students with access to information based on their own acquisition (setting an individualized pace for learning), facilitates collaboration and communication amongst students and the greater community, and exposes students to a diverse set of perspectives, all of which are optimal conditions for constructivist pedagogy. According to researchers examining constructivism, it “provides students with opportunities to take a more active role in their learning by shifting the responsibilities of organizing, analyzing, and synthesizing content from teacher to learner” (Brush and Saye, 2000, pg. 79).

Some evidence supports the dialectic link between technology implementation and constructivist pedagogy. In 1999, Becker and Ravitz evaluated a national Teaching, Learning and Computing (TLC) longitudinal study, examining the effects of a school-wide technology program on teacher instruction. The results are based on data from 4,000 4th-12th-grade teachers in over 1,100 U.S. schools. The researchers suggest that constructivist teachers (those who use a student-centered instructional approach) are more likely than traditional teachers (those who provide a lecture and do not encourage in-class discussion) to use technology in the classroom, reinforcing the theoretical connection between technology and
constructivism. Likewise, teachers in the TLC study (both intervention and comparison groups) indicated that technology played a substantial role in their instructional style. The methodology of this study, however, was limited because the researchers only present their results in the form of percentage comparisons and do not report or measure statistical significance or effect size.

Rakes, Fields, and Cox. (2006) evaluate the effect of personal computer use, level of technology implementation, and curriculum instructional practices. The researchers argue that an increase in teacher’s personal technology skill level, combined with an increase in technology implementation in the classroom, will positively predict the depth of constructivist curriculum. In essence, the increase in technology will lead to a more constructivist approach. Using the Levels of Technology Implementation (LoTI) survey (described below) and data collected from 186 4th and 8th grade teachers across 36 schools in 11 rural school districts, the researchers tested this hypothesis using multiple regression analysis. The results show that there is a moderate positive linear relationship ($R^2=.28$, $F=23.84$, $p<.001$) between personal computer use, level of technology implementation and constructivist curriculum instructional practices. Rakes et al’s (2006) study strengthens the notion that constructivism and technology are linked, while highlighting the role that individual level factors (such as technology experience) plays. As will be shown later, many comprehensive educational initiatives in the technology area link both curriculum innovation and the use of new technological practices.
Hu, Clark and Ma (2003), suggest that technology is often met by teacher resistance and overcoming this barrier requires key environmental, individual, and technological characteristics (such as perceived teacher-technology compatibility, perceived usefulness, and self efficacy). Likewise, in a case study, for example, Brush and Saye (2000) found that one teacher had difficulty understanding her role as a facilitator in the constructivist classroom. This finding, although limited in its’ generalizability, reinforces the notion put forth by educational researchers that the constructivist pedagogical approach represents a fundamental shift in teaching, requiring teachers to modify their teaching strategies such that they play a facilitative, rather than a traditional, instructional role (House, 1981). Technology implementation, therefore may ask teachers to adopt new ways of interacting with students as well as incorporating new technological tools. According to Roger’s (1983) Diffusion Theory, new and unfamiliar activities often are met with feelings of uncertainty, resulting in lower levels of implementation. Likewise, using Watzlawick’s (1984) theory of Radical Constructivism, constructivist pedagogy may be seen as 2nd order change, whereas technology implementation, alone, may be considered 1st order change. Underlying each of these theories is the notion that technology implementation using a constructivist pedagogical is a difficult task, often met by resistance and barriers.

**Measuring technology implementation**

The constructivist use of technology implementation is often embedded within programs and classroom activities as a theoretical and methodological approach to teaching. However, some researchers have also attempted to measure the use of technology for
constructivist teaching. Several efforts to develop measurement tools for technology implementation acknowledge the potential role of constructivism. Baylor and Ritchie (2002) operationalized technology use as the frequency (percentage of time) that teachers used technology for eight different classroom activities: 1.) preparing for or during classroom instruction; 2.) focusing on subject-matter content 3.) focusing on higher order thinking skills (HOTS); 4.) focusing on technology literacy 5.) used alone by students, responding to questions; 6.) used alone by students, creating 7.) used with others (in the classroom); 8.) used with a constructivist approach. The researchers did not provide the reliability or validity of this scale. Baylor and Ritchie’s (2002) scale addresses the broad range of technology implementation activities, suggesting an attempt to discern the breadth of technology implementation. While this scale clearly outlines the variation in classroom technology use, it does not reflect the depth of use.

Rakes et al (2006), on the other hand, attempted to highlight the depth of use through development of an instrument called the Levels of Technology Implementation (LoTi). The LoTi was created based on state and national teacher technology standards (Texas STaR Chart, Florida Star Chart, and ISTE’s NETS and TSSA) and uses a 7-point likert scale to determine the extent to which technology was used for “complex student projects requiring problem solving, critical thinking, and real world applicability” (Jill Stolzfus, 2006). The following items make up the LoTi:

1.) There is no visible evidence of computer access or instructional use of computers in the classroom.
2.) Available classroom computers are used primarily for teacher productivity (e.g., email, word processing, grading programs).
3.) Student technology projects (e.g., designing web pages, research via the Internet, creating multimedia presentations) focus on the content under investigation.
4.) Tool-based applications (e.g., graphing, concept-mapping) are primarily used by students for analyzing data, making references, drawing conclusions.
5.) The use of outside resources and/or interventions aid the teacher in developing challenging learning experiences using available classroom computers.
6.) Teachers can readily design learning experiences with no outside assistance that empower students to identify and solve authentic problems using technology.
7.) Computers provide a seamless and almost transparent medium for the information queries, problem solving, and/or product development (Rakes et al.; 2000, pg 414).

Creators of the LoTi indicated that each additional question represents an increased depth of technology implementation using a constructivist pedagogical approach, such that teachers can be placed along a continuum of non-use (1) to refinement (6 and 7). Stolzfus (2006) conducted a confirmatory factor analysis using a sample of teacher surveys (N=3,770) and found that each item loaded on its intended factor more highly than on another factor, indicating that the underlying construct validity is strong. Likewise, Stolzfus (2006) calculated inter-rater reliability using Cronbach’s alpha and determined that this scale maintains high reliability (α=.99).

Drawbacks of the LoTi include the lack of variability within each item or stage, as the scale does not use a likert-type response option, limiting respondents to only one stage along the continuum. Moreover, the items in the scale indicate that increased external support correlates with lower technology implementation, which is particularly questionable for highly advanced uses of technology. According to Moersch (1995), the LoTi represents
teacher progression through stages of implementation, shifting toward self-efficacy and a learner-centered (as opposed to teacher-centered) instructional method. Hence, one of the benefits of the LoTi is its reliance on theoretical and research evidence to support the underlying framework. The LoTi is a well known and frequently cited measure in the school technology implementation literature (Ertmer, Conklin, Lewandowski, Osika, 2003; Albee, 2003) and was used to inform the development of a technology implementation scale for this study.

Theoretical framework

In order to understand the nature of the relationship between technology implementation and its predictor variables, it is first important to outline a framework or perspective through which we will filter relevant research studies. The theory underlying this research study is Rogers Theory of Innovation (2003), which addresses the factors that influence an individual’s decision to implement technology. The primary aspect of the Innovation Theory used in this study is the innovation-decision stage model, which outlines the preceding stages that an individual experiences as he/she move from cognitive awareness of a technology to implementation.

Roger’s Innovation-Decision Stage Model

Roger’s (1983) theory of innovation and, specifically, the innovation-decision model are the overarching approaches guiding this research study. The innovation-decision stage model provides a structured process through which individual’s become aware and
subsequently implement an innovation. In this model, the individual passes through five specific stages leading to subsequent implementation and sustainability;

1.) knowledge gaining: the teacher is presented with information, or seeks out information regarding the technology and its uses.
2.) persuasion/attitude formation: the teacher uses the information available to form an opinion about the innovation.
3.) decision to adopt or reject,
4.) implementation occurs when the individual actually utilizes the technology within classroom curriculum.
5.) Confirmation: individuals engage in activities that reaffirm or reject the innovation. engaging in activities that will reinforce individual implementation (Roger, 1983)

Roger’s (1983) decision stage model depicts the individual-level processes that must occur in order to for teachers to move along the continuum from awareness of technology to implementation of technology. This linear model supposes that certain factors, such as knowledge about the technology, perceived ease of use, technology-user compatibility, perceived usefulness, computer self-efficacy, and positive attitudes toward technology influence and precede intended technology use (Hu, Clark, and Ma, 2003). Thus, there are individual and environmental influences that lead individuals toward increased frequency and depth of technology implementation.
Roger’s (1983) innovation-decision model is a useful means to understand how individuals come to incorporate technology into their daily routines. However, this model alone does not account for the influence of the organization or context on the individual (Klein and Sorra, 1996). As social theorists Lewin (1943), Kelley and Thibaut (1979) and Bronfenbrenner (1979) point out, individual behavior is a result of both the individual and the environment, such that teacher behavior is inextricably linked to the schools in which they teach. In order to account for this organizational level context, Roger (2003) developed a second stage model, focusing on the organization as the unit of analysis. This organizational stage model indicates that the organizations perform front-end activities that influence subsequent individual level adoption and implementation. For example, organizations set an agenda (to incorporate technology), select an innovation (a school-wide program), redefine or restructure the innovation (molding the school-wide program to their site), and clarify and routinize the innovation. This is an important contribution to innovation-decision process, as it illuminates the context within which teachers operate; the school actually adopts the program, removing the adoption decision from the individual stage model.

As indicated in Rogers (2003) Innovation Diffusion Theory, some events, activities, and attitudes are necessary antecedents to technology implementation. Below, we highlight individual and organizational level variables that have been identified as predictors of technology implementation.
Predictors of Technology Implementation

Research on technology implementation indicates that there are numerous factors associated with effective implementation that exist on multiple levels of the system. This research study focuses on factors at the individual and organizational level of the system.

**Individual**

Individuals are influenced by their context. However, as mentioned in the description of a constructivist framework, they also have previous experiences and knowledge that can act as a filter for new information, thereby influencing teachers’ ability or willingness to implement new technology. At the individual level, factors that are significantly associated with technology implementation are technology proficiency, openness to change, technology use with others, knowledge of technology and pedagogy-technology fit (Zhao, Pugh, Sheldon and Byers, 2002, and Baylor and Ritchie, 2002).

Technology proficiency enables teachers to become familiar with and knowledgeable about the various uses of technology. According to Rogers (2003), this knowledge gaining stage is a prerequisite to actual implementation. Likewise, openness to change indicates that the teacher is higher on Roger’s (1983) “S-curve”, indicating that the teacher is more innovative or open to new ideas. Teachers that are open to change require less attitudinal transformation when being introduced to new technology or pedagogical approaches. Technology use with others, or the collaborative approach to technology, encourages networking and the development of communication channels between faculty (Zhao, Pugh, Sheldon and Byers, 2002). The pedagogical fit implies that teachers have value systems that
coincide with a constructivist technological approach, and that they are proponents of acting as facilitators as opposed to lecturers in the classroom. (Baylor and Ritchie, 2002).

Teacher proficiency with technology

Teacher technology use outside of the classroom is also cited as an important predictor of technology proficiency and subsequent technology implementation. According to Baylor and Ritchie (2002), ‘the extent to which teachers use technology outside of the classroom may be an indicator of their interest and corresponding skill in using technology.’ (pg. 399) During non-school computer use, teachers have an opportunity to experiment with technological hardware and software, thereby raising their personal knowledge and subsequent levels of effectiveness. Likewise, in Rogers (2003) Diffusion Theory, individuals who are more knowledgeable are characterized as being ‘early adopters’ or ‘innovators,’ a quality that leads to faster and more diffuse implementation. Baylor and Ritchie (2002) operationalized non-school computer use as ‘the number of times technology was used at home for non-school activity.’ Likewise, Becker and Ravitz (1999) indicate that home computer access and home internet access are linked to teacher technology implementation.

Number of years teaching

There is some contradictory information as to the extent to which previous teaching experience relates to technology implementation, particularly as it relates to the constructivist pedagogical approach. New teachers are likely more experienced with new or recent technology hardware and software, as they are often younger and represent a generation of individuals who experienced early and frequent use of technology in their daily lives.
Likewise, technology proficiency is now a requirement for national teacher accreditation programs. However, experienced teachers may have the resources and experience to implement a constructivist approach, which is an underlying principle in the effective and purposeful use of computers. Thus, it is important to examine whether the number of years teaching influences the extent of technology implementation. Garet, Porter, Desimon, Birman, and Yoon (2001) in the national study that examined responses from over 1,000 teachers, found that number of years teaching is significantly and positively correlated with changes in teaching practice, although this study did not report the size of the effect.

*Socio-economic status*

Ronnkvist, Dexter, and Anderson (2000), indicate that the economic status of the community may have an impact on the amount of technology resources available in the school, and, subsequently, the level of teacher technology implementation. According Garet et al’s (2000) research on teachers, gender is not significantly correlated with changing teaching practices to include technology or a more constructivist pedagogical approach.

*Organizational Characteristics Associated with Technology Implementation*

Research indicates that school-level variables have an effect on teacher technology implementation, providing increased support for the notion that the context influences individual behavior. To name a few examples, organizational factors that influence innovation implementation and sustainability are school size, the role of a program champion (Kanter, 1988; Scheirer, 2005), high leadership support (Dirks and Ferrin, 2002), high or
positive implementation climate (Klein and Sorra, 1996), professional development (Becker and Ravitz, 1999), and technical infrastructure.

Wu, Hsu, and Hwang (2006) used log-linear analysis to examine the relationship between school size and technology use. The researchers found that smaller school size was significantly related to higher levels of technology use, although they did not provide the statistical results of their analysis.

Kanter (1988) and Scheirer (2005) indicate that the presence of a program champion is a key component to achieving sustainability of a program. While this does not specifically relate only to technology implementation, it does highlight the role of organizational factors on larger program implementation, which is perhaps more complex and multi-faceted.

Principal leadership is frequently noted to be an important predictor of innovation implementation. In a meta-analysis on the effects of transformational leadership on organizational outcomes, Dirks and Ferrin (2002) determined that trust in leadership had a strong positive relationship with belief in information provided by the leader \( (r=.35) \), highlighting the pivotal role that leadership can play in employee decisions. Byrum and Bingham (2001) provide anecdotal evidence in the form of “lessons learned” from a five-year technical assistance project performed in 12 schools attempting to implement technology.

Klein and Sorra’s (1996) model on the challenges to innovation implementation proposes that the strength of an organizations’ climate corresponds with technology implementation effectiveness (the consistency and quality of use). Klein and Sorra (1996)
did not measure or examine climate within the school organization. However, climate has been significantly and positively associated with technology implementation within other industries such as hospitals (Nystrom, Ramamurthy, and Wilson, 2002). Therefore, it is reasonable to assume that it might be relevant for technology implementation even though the researchers indicated that leadership is an integral ingredient involved in technology implementation.

_Technology infrastructure_

Technical infrastructure is an important component of many comprehensive initiatives. Specifically, the notion of technology infrastructure focuses on the level of contextual support for technology (Tornatzky and Fleischer, 1990; Lumpe and Chambers, 2001). Technology infrastructure within the school setting is the extent to which teachers are supported with available and accessible technology, information technology expertise, and communication networks for exchanging information about technology. Likewise, Ronnkvist _et al._ (2000) highlighted two key elements of technology infrastructure: available and accessible technology in/near the classroom and regularly scheduled one-on-one training and support.

A 1992 IEA Computer Education study collected data from 6,085 teachers on the relationship between technical assistance and one-on-one support in the school and technology implementation. The findings indicate that one-on-one technical assistance for teachers is more critical to subsequent student technology use than student-based technology support and assistance (Fuller, 2000). These results reinforce the relationship between
technology infrastructure and teacher technology implementation. In this regression analyses, Fuller, 2000, performed 8 separate linear regressions on the relationship between the number of hours spent providing 8 different types of technology support and student computer use; running multiple regressions on the same dependent variable increases the probability of Type I error, such that these findings could be suspect. Moreover, the data used in this study may be outdated, given the vast strides and advancement in technology over the past 8 years. However, it does provide some guidance as to how teachers may mediate the relationship between technical infrastructure and subsequent student technology use.

Strudler and Wetzel (1999) qualitatively reviewed four university pre-service teacher education case studies in order to determine factors affecting preservice teachers’ use of technology in teacher education. Strudler and Wetzel (1999) identified a wide range of program factors that could influence implementation: leadership that articulated support for technology, schools with additional grant funding, teachers that had positive attitudes toward technology, increased technology training and increased access were more likely to implement technology. This 1999 study helped to provide the groundwork for future evaluation of technology implementation predictors. However, this qualitative study, similar to much of the technology program evaluation research, is outdated and not necessarily generalizable to programs with newer technology, representing a gap in current literature.

Technical infrastructure is a component of most comprehensive technology implementation efforts and contains dimensions such as access and availability of hardware
as well as personnel assistance. While qualitative research supporting technical infrastructure is abundant, there are very few studies that systematically and empirically examine the relationship between technical infrastructure as a distinct variable and subsequent technology implementation.

While technology infrastructure is often thought of as a school-level variable, some educational technology researchers indicated that perhaps a more important indicator is the teacher-level perception of their environment. Ronnkvist et al (2000) argues for teacher-level measurement, as the perception and awareness of the technology resources and support in their school may increase their utilization of resources, “Teachers' awareness of the availability of technology support could suggest that they might actually be using the support. As teachers learn of different types of support available to them, perhaps they become more inclined to take advantage of that support – a step which could enhance how they use technology” (p. 17).

Technical infrastructure is a key factor to examine when attempting to understand predictors of technology implementation. It represents the support mechanisms in the organization that allow teachers to try out and familiarize themselves with technology in the classroom setting. As noted by Rogers (2003), trialability (i.e. the extent to which a technology may be experimented with and examined) is a key component of innovation diffusion, which influences individual-level adoption and implementation. Moreover, as long as funding is available, technical infrastructure is a highly mutable variable, unlike many other organizational variables, which are very difficult to change (i.e. size and climate).
In addition to technical infrastructure, professional development is also a well known and often cited component of comprehensive programs (NEA, 2008). There is a widespread push toward technology-centered professional development as a means to increase teacher technology use in the classroom. This is due, in part, to the rise in National Accreditation for Technology and Education (NCATE), which require technology competencies for both pre-service and current teachers (NCATE, SREB online source). Pre-service teachers are required to meet these standards through their institutional accreditation programs in order to receive licensure, and existing teachers must attend professional development seminars to maintain their licensure. In response to this growing need for technology training, schools and local education agencies have turned toward professional development as a primary means for teachers to gain the requisite technology-related skills (knowledge gaining stage in the innovation-decision model) and form positive attitudes toward computers (persuasion/attitude formation stage).

Professional development is the structured processes through which teachers are provided training to use technology for curriculum-related purposes. The purpose behind professional development for technology is to increase teacher’s positive attitudes toward technology, enhance teacher’s skill level using technology, and to increase teacher’s ability to infuse technology “seamlessly” into classroom curriculum (Baylor and Ritchie, 2002). Likewise, professional development is viewed as a means through which teachers will increase their skill, understanding, buy-in, and subsequent willingness to implement
technology (Schrum, Skeele, & Grant, 2002). Using Roger’s (1983) innovation framework, professional development, can be seen as a catalyst to enhance and encourage teacher technology implementation, by making teachers aware of the technology (knowledge gaining), providing the skill and training (knowledge gaining), and positively influencing their opinion of the technology (persuasion/attitude formation stage), all of which lead to increased technology implementation. As Schrum, Skeele, and Grant (2002) point out, professional development occurs over time through an iterative process, as “individuals move through the recognized stages…..in a spiraling fashion and learn new ideas and competencies as they are ready for them.” (pg. 259)

Dimensions of Professional Development

Researchers have identified several aspects of professional development deemed to be effective. Utilizing responses from a national sample of 1,027 math and science teachers, Garet et al. (2001) conducted least squares regression analysis to determine professional development activities that have a significant and positive effect on teacher’s self-reported knowledge and skill increases, and changes in classroom practices (toward a more constructivist student-centered model). Garet et al. (2001) found that professional development opportunities that focus on, a.) content knowledge ($\beta = .33, p < .001$), b.) opportunities for active learning ($\beta = .14, p < .001$) (i.e. providing contextual settings) and, c.) coherence or alignment with other learning activities ($\beta = .42, p < .001$) have a significant and positive effect on teacher’s self-reported skills and knowledge. This study does not examine professional development for technology implementation; however it does provide insight
into the dimensions of professional development in the school context. Moreover, it provides an indication that a wide range of professional development activities can have subsequent impact on teacher knowledge, which, according to Roger’s Diffusion Theory, is a prerequisite to teacher implementation (Rogers, 2003).

Professional development comes in many forms, such as workshops, long term professional development, and field training. Likewise, professional development for technology covers a range of topics. Sandholtz and Reilly (2004) promote using a professional development approach that focuses on curriculum, as opposed to technology, such that teachers are provided with examples or instances where technology could be incorporated into the curriculum. Similarly, Garet et al. (2002) indicate that professional development should involve opportunities to develop curriculum for technology implementation.

Much of the research on professional development is provided in the form of case studies or “best practices” (Garet et al., 2001). More recent and rigorous qualitative case studies list the components of professional development such as collaboration, student-centered pedagogy, and opportunities for real-world applications, that influenced outcomes related to professional development, such as teacher skill enhancement and change in teaching practices. However, few studies actually test these relationships empirically (Garet et al., 2001).

The National Center for Technology Innovation commissioned a study assessing teacher technology training. Utilizing a sample National Education Association members,
(N=1934, 90% were classroom teachers, 9.6% were instructional assistants), researchers administered a telephone survey in 2006. The researchers found that teachers more than half (60%) of the educators reported participating in technology training, but that this training was more effective for non-instructional tasks (NEA, 2008). The educators reported that the training was geared more toward administrative uses, research and communication than on preparing teachers for technology using a constructivist pedagogical approach.

Beyerbach, Walsh, and Vannatta (2001) evaluated a nationally funded pre-service teacher program, known as PT3 that aimed to infuse technology into its curriculum. The researchers found that professional development for pre-service teachers has effects on both technology integration and instructional pedagogy. In this two-year longitudinal study, 300 pre-service teachers were exposed to professional development opportunities that included hands-on experience with computer technology to support constructivist thinking, two-way interactive video conferencing, and field experiences in technology-rich classrooms. In their evaluation, the researchers analyzed data from surveys, focus groups, classroom observations, and pre-service teachers’ work. Over the course of the two-year program, pre-service teachers reported gains in technology proficiencies. The most notable gain, however, was in the area of instructional methods of technology integration, which increased from 15.9% to 68.9%. Upon further investigation of focus group data, the researchers found that teachers “changed their views of technology infusion from thinking that they would teach and learn about technology to thinking they would use technology to support student learning.” (Beyerbach et al. 2001, pg. 106). This study used a staggered implementation pre-
post non-randomized control group design, where pre-service teachers reported on their
knowledge and experience prior to and after the 2-year course. This study did not examine
technology transfer from professional development into a real-world classroom setting,
although it does paint a picture of the potential benefits of professional development for
technology-related classroom instructional strategies.

Barriers to Professional Development

The results of these research studies may lead one to conclude that technology-
centered professional development is a straightforward means to increase teacher technology
use. However, several research studies highlight the barriers that teachers experience in
moving from a traditional to constructivist pedagogical approach. For example, according to
Blumenfeld, Fishman, Krajcik, Marx, & Soloway (2000) professional development is often
met with individual and organizational resistance. The researchers published a multiple case
study reporting their experiences with a professional development program in an urban
school system characterized by high poverty, high rates of minority, and low achievement
scores. The program focused on developing a constructivist instructional method using
technology within four “science-units” lasting 8-12 weeks in duration. In order to learn how
to implement this curriculum, teachers attended two-week summer workshops and received
ongoing in-house support from a technology specialist. The researchers identified multilevel
barriers to adoption, implementation, and routinization. Specifically, the constructivist
curriculum required high levels of technology skill and a departure from the traditional
teaching role. For teachers without these requisite characteristics, constructivist instruction
also necessitated professional development, collaboration, and planning. Teacher’s expressed concern regarding their ability to uphold student achievement scores in the constructivist curriculum. This caused many teachers to revert back to traditional instructional practices. The restricted time schedule for teachers created an additional barrier, as many of these professional development sessions were offered during or directly after school (a time often used for lesson planning). While extra-curricular off-site professional development opportunities were available, the school system could not afford to pay for teacher time to attend the training sessions. The researchers reported that teachers also spent more time on aspects of the curriculum that related to the teachers educational background and experience, thereby condensing the time allotted for technology integration. It seems that the teacher’s value incongruence with the constructivist instructional approach caused teacher resistance (House, 1981).

The researchers conclude by providing a best practices approach to constructivist instruction using technology, highlighting administrative support of peer interaction through flexible scheduling and an organizational culture of collaboration as two primary ways to increase technology use in the classroom. Here, Blumenfeld et al. (2000) provide clear examples of professional development limitations regarding limited time and the arduous task of changing pedagogical approaches from traditional to constructivist.

Sandholtz (2004) indicates that the barriers to professional development are also related to the limited content domain addressed. Specifically, professional development often focuses on computer literacy and basic skill acquisition. Similarly, Schrum (1999)
notes that professional development programs often focus on skill development, without adequately portraying how these skills can transfer into instruction or why transitioning to a new form of instruction may be beneficial to both the teacher and the learner.

Likewise Schrum (1999) suggests that these shortcomings are due to the nature of traditional professional development programs “one-size fits all” approach, which do not take into account individual differences such as teachers’ level of preparedness, learning style, and current interests. This harkens back to Everett Rogers (2003) notion of earlier and later knowers, which indicates that teachers’ past experience and available communication network greatly impacts their readiness to use technology. In order to compensate for these potential hindrances, on-going, in house technology support and channels through which discussion, understanding, and learning about technology can occur should supplement professional development programs.

In 2003, researchers conducted an evaluation of the Preparing Tomorrows Teachers to Use Technology (PT3) grant, which infused the pre-service education program at Arizona State University with grant funding to create technology-related education opportunities (Brush, T., Glazewski, K., Rutowski, K., Berg, K., Stromfers., C., Van Nest., M., Stock, L., and Sutton, J., 2003), a comprehensive and nationally distributed funding initiative. In this particular site, the pre-service teachers took part in a series of professional development opportunities 1.) Pre-service teachers were required to attend at least 2 modeling sessions, in which faculty members modeled technology-enhanced curriculum 2.) Pre-service teachers were placed in classroom settings, where they could witness and apply their technology
Pre-service teachers were provided with ongoing technical support from champion graduate students, who aided in both pedagogical and technical questions surrounding technology. Brush et al (2003) collected self-report qualitative data from 100 pre-service teachers and faculty to determine whether the technology-centered professional development program had an effect on teacher attitudes or teacher technology use. The results indicate that the program helped to increase positive attitudes toward students and technology, as well as increase the use of technology, although the teachers reported difficulty implementing technology into classrooms that lacked additional support. Brush et al’s (2003) study reinforces the notion that professional development provides information (for Roger’s, 1983, knowledge gaining stage) and increases positive attitudes toward technology in the classroom (for Roger’s, 1983 attitude formation/stage), all of which subsequently lead to technology implementation.

Professional development contains multiple dimensions; however the underlying notion is that it will increase teacher’s familiarity with and willingness to use technology. Research on professional development, while widespread, primarily relies on anecdotal “best practices” or case studies to support research claims. In order to validate these arguments, it is important to examine the concept of professional development related to technology implementation in a more systematic and empirical fashion.

Professional development is a key variable to examine for several reasons. First and foremost, educators and policy makers rely heavily on professional development to obtain teacher buy-in and provide the appropriate skill training, which, according to Roger’s (1983),
are necessary precedents to technology implementation. This is exemplified by the National Council for Accreditation of Teacher Education’s (NCATE) requirement for both pre-service and in-service teachers, indicated that continued professional development is a core tenant of national standards. Given the national requirements for continued professional development, it is a means to reach teachers and create standards across the nation. In addition, this is a highly mutable variable, one of the few that can be modified readily in order to disseminate new and updated information to teachers and to move teachers from the knowledge gaining to implementation stage of innovation diffusion.

*Policy and Comprehensive Initiatives to Support Technology Implementation*

The process of professional development and technical infrastructure often do not occur in isolation. These components often occur as one part of broader initiatives, where it is unclear how the interplay of such specific activities may interact with the broader context. Therefore, we will examine in this section the relationship between comprehensive initiatives, professional development and technical infrastructure.

The federal government has, for years, aimed to improve technology education, particularly in low SES or high need areas. In order to achieve these technological advancements, the federal government has endorsed policies to increase technology use in the school system. For example, the Office of Educational Technology (OET) produced The National Education Plan in 2005, which outlines barriers and recommendations for including technology into curriculum. The plan represents the national impetus toward technology, as well as an attempt to standardize implementation throughout the U.S. school system. In
accord with OET, the National Council for Accreditation of Teacher Education (NCATE), using evidence from International Society for Technology in Education (ISTE), enacted standards for technology training for pre-service teachers. As noted earlier, in addition to pre-service accreditation standards, Title I of the 2001 NCLB Act allocates funding for comprehensive technology programs in low SES schools.

Corresponding with federal initiatives, states are also beginning to develop initiatives and comprehensive school-wide programs. For example, Virginia’s Department of Education recently partnered with the Governor’s office to integrate data systems and online assessments; Louisiana incorporated an online professional development program for in-service teachers; West Virginia created a virtual school for students (West Virginia Virtual School). Many of these and other statewide programs are at least partially funded by the U.S. Department of Education.

According to the U.S Department of Education, comprehensive school reform programs are “designed to foster coherent school-wide improvements that cover virtually all aspects a school’s operations, rather than piecemeal, fragmented approaches to reform.” (U.S. Department of Education, 2008). Clearly, this is a broad definition of what constitutes comprehensive initiatives. Comprehensive programs represent a formal dissemination effort, wherein key components are systematically provided in order to improve the quality of the school. Comprehensive technology programs that have shown to be effective often contain common elements. According to the U.S. Department of Education (2008) there are eleven components of comprehensive school reform programs:

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1. employs proven methods and strategies based on scientifically based research
2. integrates a comprehensive design with aligned components
3. provides ongoing, high-quality professional development for teachers and staff
4. includes measurable goals and benchmarks for student achievement
5. is supported within the school by teachers, administrators and staff
6. provides support for teachers, administrators and staff
7. provides for meaningful parent and community involvement in planning, implementing and evaluating school improvement activities
8. uses high-quality external technical support and assistance from an external partner with experience and expertise in schoolwide reform and improvement
9. plans for the evaluation of strategies for the implementation of school reforms and for student results achieved, annually
10. identifies resources to support and sustain the school's comprehensive reform effort
11. has been found to significantly improve the academic achievement of students or demonstrates strong evidence that it will improve the academic achievement of students (U.S Department of Education, online 2008, Eleven Components of a Comprehensive School Reform Program)

Attention to these components has occurred in research on comprehensive programs. For example, professional development, technical assistance and support, and collaborative or shared decision-making are all components common to technology implementation programs. (Zhao et al, 2002; Wong and Meyer, 1998)

Project Technology Helping Restructure Educational Access and Delivery (THREAD) represents another comprehensive program in the educational technology field. Project THREAD was funded by the U.S. office of Education to prepare pre-service student teachers for technology implementation in K-12 schools. (Strudler, Archambault, Bendixen, Anderson, and Weiss, 2003) Strudker et al. (2003) evaluated Project THREAD using qualitative and survey data from teachers (N=153) in schools categorized as either “professional practice” schools (N=27) or “other public schools” (N=127). The researchers did not explicitly outline the differences between professional practice vs. other public
However, in the analysis, these categories were used as treatment vs. control groups, respectively. Project THREAD focused on several components aimed to increase teacher technology use, such as “implementing a collaborative planning process, providing professional development opportunities, increasing access to resources, and offering one-to-one support” (pg. 44) Embedded within Project Thread is the notion that, through dissemination and implementation of a widespread program, teachers may be more likely to use the constructivist approach. In a chi-square analysis, the researchers found that student teachers engaged in professional development reported significantly more use of technology for higher-order thinking in students. The results provide enhanced support for the benefits of comprehensive programs. However, the article did not provide effect sizes, did not provide a clear outline of the number and types of analyses performed and generally reported findings in terms of percentages or frequencies. While Strudler et al. (2002) linked goals to program components and measures, the researchers did not examine how specific program components related to technology implementation, representing a gap in the literature. Future research should attempt to discern which aspects of these comprehensive programs are essential to implementation.

**Synergy across comprehensive programs**

The implicit notion of comprehensive programs is that, by providing several components at once, the program will have a synergistic or multiplicative effect on technology implementation. For example, the outcome of professional development will be exponentially more potent if it is provided in schools that are higher in technical support,
stakeholder and community involvement, and school leadership than in schools lower in such assets.

Researchers indicate that combining several approaches will lead to increased technology implementation. For example, in recent years, national teacher accreditation programs developed new technology standards for preservice teacher education programs. In an attempt to meet these national technology standards and train teachers to use more effectively, many programs incorporated comprehensive strategies to train teachers and infuse technology. Kay (2006), a researcher in the educational technology literature, reviewed 68 studies addressing technology implementation. In this qualitative review, Kay (2006) highlighted several strategies to implement technology that cut across most of the preservice teacher education programs, namely:

“single technology courses; mini workshops; integrating technology into all courses; modeling technology use; using multimedia; collaboration among preservice teachers, mentor teachers, and faculty; practicing technology in the field; and improving access to software, hardware, and/or support.”(pg. 383)

According to Kay’s (2006) research, programs that used a greater number of strategies for technology implementation were more effective. However, most preservice teacher programs used only one or two of the abovementioned strategies. This qualitative review indicates that incorporating a range of approaches to technology may increase preservice teacher’s ability and willingness to use technology. Kay’s (2006) qualitative review does not provide a systematic analysis of the program components and therefore cannot be generalized to other contexts or situations. Clearly, preservice teacher accreditation programs cannot be
entirely likened to current teachers’ experiences in the classroom, as there are contextual factors in classroom settings that cannot be simulated in preservice education programs. Kay’s (2006) study provides a prime example of the type of anecdotal or descriptive studies available in the educational technology literature. While it provides some exploration and guidance into the field, it does not systematically organize or analyze data, representing a major gap in the field. Thus, an important contribution to the educational literature would be to measure comprehensive program factors using more advanced statistical analyses.

The number of implementation-related variables and potential interactions amongst these factors creates a level of complexity that is difficult to disentangle in any one study. Therefore, for the purposes of this research, we will narrow the scope of the study to include only a few key variables associated with implementation, focusing primarily on mutable program level factors influences, namely professional development and technical infrastructure. These two factors have been widely cited in the research as predictors of technology implementation, although most studies are limited in the methodological rigor with which they examine these factors. Given the fact that these components are widely used as part of funded school-wide programs, it is necessary to re-examine them using more advanced statistical techniques.

Gaps in the Literature

Previous research provides a framework for examining the predictors of technology implementation, particularly for professional development and technology infrastructure. However, there are multiple limitations in the existing research.
**Qualitative Research and Limited Generalizability**

Much of the research on professional development, technical infrastructure and technology implementation is anecdotal, providing “lessons learned” and inferences from the researcher, or qualitative case studies, limiting the researchers ability to generalize to larger and different samples (Strudler and Wetzel, 1999; Brush et al., 2003; Kay, 2006). These types of studies were particularly useful during the early stages of technology implementation research, when predictors needed to be identified and associated dimensions explored. Given this previous research, it is now possible to examine these factors using a quantitative approach, which allows researchers to collect data from larger populations across a much wider regional area in order to further test the relationships posited in qualitative and descriptive research.

**Quantitative Research**

Nested data structure

While most of the research is qualitative, those studies that incorporate multiple regressions often do not partition the variance that is due to school-level vs. teacher-level effects, thereby violating the assumption of independence of observations. Multiple regression does not account for the nested structure school data, ignoring contextual effects and increasing the amount of shared variance. Hierarchical Linear Modeling is a statistical technique that overcomes many of these barriers by taking into account the nested structure of teacher-level data and reduces multicollinearity that is due to sharing variance (i.e. sharing context) across variables.
Data analyses

Moreover, the aforementioned research studies often provide only descriptive statistics (e.g. Becker and Ravitz 1999), despite the large amount of data collected, making it difficult to draw conclusions on the nature of relationships between variables. Likewise, the researchers frequently perform a large number of regression analyses, using several predictors on one dependent variable, thereby artificially inflating the probability of a Type I error (Rakes et al, 2006). It is important to re-examine variables such as professional development, technical infrastructure and technology implementation using more appropriate statistical techniques, which allow inclusion of multiple variables in one model.

Cross-level effects

Along with providing a flexible model that allows for nested data structure, HLM also offers an opportunity to examine the interaction effects between variables at two levels. This is in line with the ecological approach and research on technology implementation, which denotes that both organizational and individual level variables influence technology-related outcomes. Quantitative research in education primarily relies on multiple regression, which can examine interaction effects. However, in multiple regression using two-level data, there is a heightened Type I error probability because teachers and schools share variance. In order to correct for this, HLM provides an opportunity to partition variance due to school vs. teacher, thereby providing a better estimation of the interaction effect.

Research Questions

1. Is there a significant between-group effect on technology implementation?
2. Is there a significant and positive relationship between professional development and technical infrastructure when controlling for race/ethnicity?

3. Is there a significant difference in technology implementation among schools utilizing a comprehensive approach (i.e., IMPACT) and matched schools not utilizing a comprehensive approach (non-IMPACT)?

4. Does the comprehensive program IMPACT significantly and positively moderate the relationship between professional development and technology implementation?

5. Is there a significant and positive relationship between technical infrastructure and technology implementation when controlling for race/ethnicity?

6. Does the comprehensive program IMPACT significantly and positively moderate the relationship between technical infrastructure and technology implementation, when race/ethnicity is included in the model?

Hypotheses

Professional Development

$H_1=$ Professional development will explain a significant amount of variance in technology implementation when number of years teaching, home computer access, and home internet access are included in the model. Higher levels of professional development will be associated with higher levels of technology implementation.

Technical Infrastructure

$H_2=$ Technical Infrastructure will explain a significant amount of within-group variance in technology implementation when number of years teaching, home computer access,
and home internet access are included in the HLM model. Higher levels of perceived technical infrastructure will be associated with higher levels of technology implementation.

IMPACT

H₃= IMPACT will explain a significant amount of between-group variance in technology implementation when number of years teaching, home computer access, and home internet access are included in the model.

Interaction of IMPACT and Technical Infrastructure

H₄= The interaction between IMPACT and technical infrastructure will explain a significant amount of variance in technology implementation when number of years teaching, home computer access, and home internet access are included in the model.

Interaction of IMPACT and Professional Development

H₅= The interaction between IMPACT and professional development will explain a significant amount of variance in technology implementation when number of years teaching, home computer access, and home internet access are included in the model.

Methods

Comprehensive Program and IMPACT model

Comprehensive initiatives are widespread programs aimed to increase technology use in schools through the use of multiple integrated components. IMPACT is a comprehensive school-wide technology implementation model aimed toward increasing technology implementation, developed specifically to address barriers in low SES schools or high
technology needs schools. IMPACT emerged from a national initiative in NCLB, known as Title I, wherein government agencies provide funds to State Education Agencies for technology advancement in public schools.

Originally, the federal government prioritized technology (setting the agenda) and, in response, researchers employed in North Carolina’s State Education Agency (SEA) developed IMPACT (selecting an innovation), and then passed IMPACT down to Local Education Agencies (LEA’s) and onto schools for schools to test it and define how it works in their local context (redefining and restructure the innovation), to determine sustainable components (clarify and routinize).

There are several components of IMPACT such as an advisory board, technology personnel, professional development, collaboration and flexible scheduling, all of which act in concert to provide teachers with an optimal support system within which to implement technology. Thus, many of the components target teachers as the primary change agent, ultimately responsible for technology implementation. IMPACT is intended to create school-level as well as teacher-level changes, so that teachers will be more likely to implement technology. Embedded within the IMPACT program is the notion that the constructivist use of technology is an effective instructional method that provides students with long-term computer skill sets and increases the amount of information students learn.

As stated previously, the IMPACT grant is provided through federal funding to schools with Title I status and high technology need. Schools that qualified for the IMPACT grant were provided with 1.3 million dollars over a period of three years. Under guidelines
of No Child Left Behind (NCLB), there is a great deal of flexibility in the IMPACT model and allotment of monies provided by the IMPACT grant. They were able to choose educational software and hardware, along with supplemental technologies (i.e. smartboards and projectors). However, in order to continue receipt of grant funding across the three years, each of the 11 schools agreed to implement several components.

IMPACT creators developed an initial rubric to emphasize components of the IMPACT model, which provide guidelines for the infusion of technology. These components include: establishment a Media Technology Advisory Committee (MTAC), hire a Media Coordinator and Technology Facilitator, allot 25% of funding toward staff development, allocate time for collaboration among teachers, and create flexible scheduling for the media center.

*Media Technology Advisory Committee*

Under IMPACT guidelines, creation of the Media Technology Advisory Committee for each school is the first priority for any school working toward technology implementation. This committee is made up of the principal, the technology facilitator, media coordinator, and representative teachers. In some cases, community members are also asked to join the MTAC. Members of MTAC make decisions about the type and process through which technology will be infused into their school. The MTAC is a necessary component of the IMPACT Model, as the state uses a site-based management model, and does not mandate the type of technology provided to the school, thereby allowing each school with great flexibility in their technology-related decisions. Thus, the MTAC provides each school with an
opportunity to work collaboratively and utilize a feedback system for future technology-related decisions.

**Personnel**

In order to establish the MTAC committee and initiate technology implementation, each intervention school is required to hire a full-time media coordinator (MC), a full-time technology facilitator (TF), a technician, and a media assistant. In schools that have larger student memberships (>500), the media assistant and technician are full-time positions. The media coordinator was previously considered the media librarian. Thus, the MC is typically an in-house hire, familiar with the students, teachers, principal, and technology available in the school. The technology facilitator, on the other hand, is often an external hire, who is well versed in the area of educational technology (N.C. has special licensing requirements for these individuals, as well as for media coordinators.) The MC and TF are expected to work together to keep track of technology use within the school and to provide technological support for teachers and students. This involves supplying ongoing staff development as well access to technology. Additionally, the presence of a technician allows the technology facilitator to engage in planning, modeling, and teaching activities, instead of focusing on troubleshooting problems with equipment.

**Professional development**

Professional development is a core component of the IMPACT program. In fact, each school is required to spend 25% of their total funding toward staff development as a part of the federal EETT funding regulations. This corresponds with research in the area of
educational technology, indicating that regular staff development can change teachers belief systems about technology, subsequently increasing comfort and technology use within the classroom. (Baylor and Ritchie, 2002) Creators of the IMPACT model allow schools to develop staff development strategies based on the school’s need and technology plan, thereby generating flexibility and variation among schools.

Each IMPACT school engaged in multiple types of staff development, based on differing modes and content standards. Some technology training sessions attend to more universal technology issues, such as copyright protection or how to integrate instructional technologies within learning environments, whereas others involve specific educational technology software training. Examples of common staff development experiences include Intel “Teach to the Future,” ENTech (also known as NC Best), and seminars with David Warlick (a well-known educational technology expert). At most schools, teachers also engaged in training to use specific equipment or applications; common examples of this type of professional development include Activeboard training, web design training, and training in Kidspiration.

Each of these staff development approaches differ in terms of cost. Thus, many schools alter the mode through which they incorporate staff development. At times, schools hire technology specialists to train teachers in-house, while other times engaging in externally located technology workshops. Schools also conserve staff development monies by sending a staff member to a training session, who subsequently trains the remaining
teachers (creating internal specialist). Most schools employ multiple training modes with varying levels of specification throughout the year.

**Collaboration**

Once teachers gain technology-centered knowledge and support, it is necessary to employ this information in the classroom curriculum. In order to perform this task more efficiently, teachers are required to meet in order to discuss technology implementation plans. Incorporating technology can be a burdensome task to individuals new to the area of educational technology. By working together, teachers can increase co-learning and efficiency by reducing the total workload related to technology implementation. Collaboration may also increase teachers’ perception of technology-related support, which may directly relate to teachers comfort using technology in the classroom. Within the IMPACT model, collaboration is defined as the sustained cooperative planning effort among media coordinators, technology facilitators, and classroom teachers. The actual implementation of collaborative planning differs across project schools. Some schools provided substitute teachers at regular intervals (e.g. every nine weeks) to allow teachers to plan their lessons, while others paid teachers to come in on weekends or in the afternoon. However, at all schools, teachers had the opportunity to work with their grade-level peers and with their school’s media and technology staff to build lessons that capitalized on their school’s resources.
Flexible scheduling

In order to distribute technology access evenly across classrooms, the IMPACT model requires that schools switch to flexible scheduling. In the media library, there are often resources that cannot be made available in every classroom such as computers for every child and the in-class support of the technology facilitator or media librarian. Under flexible scheduling, teachers may utilize the media library according to their technological needs. Prior to flexible scheduling, teachers were allowed to utilize the media library only during previously specified time intervals each week. Unfortunately, these time intervals did not always coincide with technology-centered lesson plans, thereby forcing the teacher to redesign the curriculum based on availability of the media library. Flexible scheduling, however, allows teachers utilize the media library when the lesson plan calls for technology-intensive curriculum. Flexible scheduling also applies to the school’s computer labs that were not allowed to operate on fixed schedules.

Design and Timeline

This study is a quasi-experimental posttest only matched group design. Schools consisted of those who received the IMPACT grant (N=11) and comparison schools (N=11). Descriptive school-level data were collected during the fall of 2003. Teacher-level self-report data utilized in this study were collected during fall (roughly September-October) of the 2005-2006 school year, the third year of funding and the third year of the comprehensive program (IMPACT) implementation (refer to Figure 1). Intervention (IMPACT) schools were notified that they received the IMPACT grant (X₁) in the spring prior to fund
distribution. In Fall, funds were dispersed to the IMPACT schools (X₂). Data from a teacher survey (i.e., the STNA) was collected from IMPACT schools in fall of 2005 (O₁) and from Control groups in the spring of 2006 (O₂). The time lapse between the IMPACT and Control data collection may have been influenced by history, representing a threat to internal validity. The evaluation researchers attempted to document any and all historical influences on the outcome variable, technology implementation, and none were found for this time period.

Participants

Schools

Data from 22 North Carolina schools involved in a national funded technology grant (the Enhance Education through Technology Grant) will be utilized. This competitive grant allows schools from high poverty areas, or those in need of technology improvement, the opportunity to utilize funds for technology that facilitates learning and prepares students for today’s technologically advanced workplace (NCLB, 2006). Eleven schools in North Carolina applied for this grant and received funding in 2001. The government provided each of these schools with $433,333 every year for three years in order to integrate technology into regular classroom curriculum.

Any Title I North Carolina school was allowed to apply for the competitive federal IMPACT grant. From the pool of applicants, intervention and comparison schools (N=22) were selected to take part in this IMPACT evaluation study. This intervention school selection process included meeting the deadline for submission and displaying a need for
technology in the school. The intervention schools vary greatly according to their size, their location (urban vs. rural), and within the lower SES bracket they vary greatly. The control schools were chosen from the pool of IMPACT applicants and were matched based on several criteria, namely as percentage of students receiving free lunch, size of school, percent minority, and student performance in reading and math schools. The evaluators attempted to match groups on all of these variables. Given the variability across schools, this was not always possible. Researchers matched schools on as many variables as possible, generally matching on at least reading and math scores and SES. The nonrandom selection of schools may indicate a bias in teacher responses, as they do not represent the population of schools throughout all of North Carolina. Rather, this sample represents teachers from low-income school districts, working in schools in high need of technology improvement. Figure 2 provides a comparison of the percent of students receiving free lunch for IMPACT vs. non-IMPACT schools. As can be seen in Figure 2, researchers attempted to match schools based on SES, as approximated by the percent of students receiving free lunch. Figure 3 presents comparison of percentage of minority students for IMPACT vs. comparison schools. As can be seen in Figure 3, the racial/ethnic make-up of the student populations differed somewhat between IMPACT vs. non-IMPACT student populations.

Teachers

Participants in this study are teachers in each of 22 schools involved in the IMPACT grant. All teachers employed in these schools were asked to respond to a measure of School Technology Needs Assessment (STNA). Participants in this study are teachers who
responded to the STNA questionnaire and the demographics survey, N=385. Principals and technology facilitators who filled out the survey will be excluded from the analysis. Due to a high rate of turnover in the impact and control schools, only 60% of the original teachers continued into their second year of teaching. Although this is a common occurrence in the public school system (specifically those with low SES), it poses a threat to internal validity due to the high rate of attrition.

One of the requirements under the IMPACT grant is that all teachers must fill out evaluation surveys. As there was a high rate of turnover in all of the schools, this study only includes teachers who continued to teach into the third year of the IMPACT grant. Despite the requirement that all teachers fill out the surveys, some were absent or simply did not return the surveys. As is the case in most public schools, there is a larger female population among IMPACT and control teachers.

Measures

The survey used in this study is a quantitative self-report measure known as the Student Technology Needs Assessment (STNA). Using evidenced based practices and guidelines¹, the STNA was developed by SouthEast Initiatives Regional Technology in Education Consortium (SIERTEC) to evaluate components of the IMPACT model.

Exploratory factor analysis (EFA) using sample of teacher STNA surveys (N=2050) from 48

¹ References included “enGauge framework, STaR Chart, National Education Technology Standards for students, teachers and administrators, National Staff Development Council Standards for staff development, IMPACT Guidelines, and Seven Dimensions for Gauging Progress guide (CEO Forum, 2000; International Society for Technology in Education, 2000a, 2000b, 2002; Milken Exchange, 1998; National Staff Development Council, 2001; North Central regional Educational Laboratory, 2000; Public Schools of North Carolina, 2005” (Sullivan, 2005)
schools in North Carolina revealed a 13 factor structure, with eigenvalues greater than 1, consistent with the intended underlying components of the survey (Sullivan, 2005).

Likewise, Sullivan (2005) calculated reliability for each scale using Cronbach’s $\alpha$, which will be presented below. Scales from the STNA utilized for this study include the following variables: gender and race/ethnicity (1,2), number of years teaching (3), home internet access (4), home computer access (5), professional development participation (6), technical infrastructure (7), and technology implementation (refer to Appendix A).

1. Gender: Teachers were asked to report their gender as either male (0) or female (1).

2. Race/ethnicity: Teachers were asked to report their race/ethnicity as 1=black, 2=Hispanic, 3=American Indian, 4=Asian, 5=white, 6=multi-racial, 7=other. Due to low variability in teacher race/ethnicity, only African-American and white were included in the sample. This measure was then dichotomized so that 0=white and 1=African-American.

3. Number of years teaching. Teachers were asked to report the number of years teaching using the question, “I have been teaching for…” Response options included less than 1 year, more than 1 year but less than 3, more than 3 years but less than 7, more than 7 but less than 15, and more than 15 years (assigned in the data set as 1,2,3,4, and 5 respectively).

4. Home Computer Access. Teachers were asked to report home computer access using the question, “Do you have access to a home computer?” Response options were no=0 and yes=1.
(5) Home Internet Access. Teachers were asked to report home Internet access using the question, “Do you have access to Internet at home?” Response options were no=0 and yes=1.

(6) Self-reported Teacher Professional Development Participation ($\alpha=.89$, $N=1,482$, Sullivan, 2005) The professional development scale used in this study consists of 7 items with a 3-item response option (1=Yes, 2=No, and 3=I don’t know.) Participants were asked whether, in the last 12 months, they participated in professional development about educational technology. The professional development scale does not solely examine participation in constructivist-focused professional development activities. However, the majority of items address participation in professional development activities for constructivist instructional practices, such as items “I participated in professional development opportunities, examining research-based practices in technology-enhanced classrooms”, and “I participated in professional development opportunities examining learner-centered teaching strategies in technology-enhanced classrooms.” For the professional development score, the sum of all items was computed.

(7) Self-reported Teacher Technical Infrastructure ($\alpha=.85$, $N=1,799$, Sullivan, 2005). The technical infrastructure scale used in this study consists of a 7-item Likert-type response option. Participants were asked the degree to which they agree or disagree with the statements (1=strongly agree, 2=agree, 3=neither agree or disagree, 4=disagree 5= strongly disagree). Sample items include: “Adequate access to
technical support is available (e.g. to troubleshoot hardware or software problems), and “Adequate staffing is readily available in technology facilitator and/or technology assistant positions.” For the technical infrastructure score, the mean of all 7 items was computed.

(8) Self-reported Teacher Technology Implementation (α=.89, N=1,489, Sullivan, 2005). This variable was measured using a 5-item Likert-type scale. Teachers were asked the degree to which the statements (1=strongly agree to 5=strongly disagree) were accurate regarding their classroom. It should be noted that the measure does not solely focus on using technology for constructivist purposes. Rather, this measure examines several uses of technology, including using technology to plan lessons, interact with parents, and access professional development resources. The measure only explicitly examines constructivism, in the following sample questions; “Teaching is more student-centered when technology is integrated into instruction” and “Teaching practices emphasize student uses of technology as a regular part of teaching strategies (e.g. project-based or cooperative learning).”

Data Analysis

(1) Missing Value Analysis: The original data set included a larger sample of teachers (N=562). We removed technology facilitators, media coordinators, and principals, from the data set (N=525). In addition, we only included those teachers who responded to the demographic survey, which was collected in year 1 (a different time than the STNA data), which also reduced the sample size (N=385). To examine the
potential effects of missing data, we analyzed the data using the full sample of teachers (excluding demographic variables) and found a similar pattern of results. The data with race/ethnicity included are presented here. There are several options for treating missing data, such as excluding cases listwise, replacing the missing values with the mean, and imputing missing values based on regression analysis using other correlated variables as predictors. Given that race/ethnicity is a dichotomous and categorical variable, it did not make conceptual sense to impute race based on other correlated variables. In addition, imputation was considered for the variable Home Computer Access. However, there were no significant correlates and there was not enough variability in the item to warrant imputation.

(2) Correlation Analysis: Correlations among gender, number of years teaching, home computer access, home Internet access, race/ethnicity, technology infrastructure, professional development, technology implementation and the comprehensive program (IMPACT) were examined. Diagnostics revealed that of the covariates listed in hypothesis 1-4, only race/ethnicity was significantly correlated to the predictor variables professional development and technical infrastructure and the outcome variable technology implementation (refer to Table 1, Appendix A). Thus, only race/ethnicity was included as a predictor in subsequent HLM analyses.

(3) Descriptive Statistics: The Mean (M), minimum (MIN), maximum (MAX), Standard Deviation (SD) skew and kurtosis of each scale were calculated and each of these is presented in Table 2 below (refer to appendix A). The scales for professional
development, technical infrastructure and technology implementation were all significantly negatively skewed. In order to examine the effect of skew further, we transformed professional development using the inverse square-root and transformed technology implementation using the inverse log. A similar pattern of results was found using both transformed and untransformed data. In order to aid in interpretability, only the untransformed data is presented here.

(4) Centering: Each scale was centered so that zero represented the mean. This reduces non-essential multicollinearity common in interaction terms and aids in interpretation.

a. Grand mean centering: Intercepts are adjusted for differences in the predictor across units of analysis. Between person/group differences on mean scores on the variable contribute to parameter estimates. Grand mean centering creates a meaningful intercept based on the mean for the entire sample and reduces the amount of multicollinearity shared between the predictors. The continuous predictor variables in this study (professional development and technical infrastructure) were grand mean centered.

(5) Multilevel Modeling (MLM):

Data will be analyzed using MLM in SAS. MLM includes hierarchical linear modeling, a statistical modeling technique that allows the researcher to fit two-level school effects models. Two-level school effects refer to situations in which you have data at two levels within an organizational hierarchy such as teachers within schools and you would like to examine the behavior of a level 1 (individual/teacher level) outcome as a function of both
level-1 and level-2 predictors (i.e. individual and school level predictors, respectively.) (Singer, J, 1998, p. 325; Hawkins, Guo, Hill, Battin-Pearson, & Abbot, 2001). HLM represents an improvement over past statistical methods due to a.) improved estimation of individual effects, b.) ability to model cross-level effects and c.) ability to partition variance-covariance components (Raudenbush and Bryk, 2002).

Past research often ignored the nested structure of data, a condition that violates the assumption of independence among observations and increases the probability of Type I error. While many researchers were able to recognize the problems inherent in conventional linear model techniques, the error continued due to the limitations of conventional statistical techniques (Raudenbush and Bryk, 2002). Multilevel Modeling, however, represents progress toward a more accurate analytic technique, which allows for the nested structure within systems. This is particularly useful for educational research, which, according to Raudenbush and Bryk (2002) is often challenging due to the nested structure of the system with observations of individuals nested within classrooms and schools. In this study we focus on two levels of educational research foci: the level of the individual (teacher) and the level of the organization (school).

In accord with allowing for contextual effects, MLM also allows for multiple predictors at multiple levels of analysis. In this case, we have school level data (IMPACT vs. Comparison) and teacher-level data (reported professional development, technical infrastructure, and teacher technology implementation). The small sample of schools (N=22) limits the number of level 2 variables that can be utilized in the analysis; Raudenbush and
Bryk (2002) suggest using 1 variable for every 20 observations. Hence, this study is limited as to the number of level 2 variables that can be included. Still, the use of a statistical technique that allows for the contextual nature of educational research data is an improvement upon previous analytical techniques.

MLM allows for missing data, and determines the percent of inter vs intra-organizational variance. MLM includes predictors at multiple levels of analysis, allows for interaction between levels, and has flexible error structures and/or random effects. In this study, teacher-level (level 1) and school-level (level 2) variables are included.

Using MLM, data is entered in stages and, at each point along the analysis, the results will inform whether there is a significant level of variance to warrant continued analyses. This reduces the number of tests performed on the data, thereby decreasing the probability of a Type I error. The following section provides a list of the potential analyses to be conducted in SAS:

**Fully Unconditional Model:** Used to establish whether there is a significant between-group (school-level) variance in the dependent variable to move forward with subsequent analyses.

**One-way ANCOVA Model:** Used to establish whether professional development is significantly associated with technology implementation when controlling for race/ethnicity.

**One-way ANCOVA Model:** Used to establish whether technical infrastructure is significantly associated with technology implementation when controlling for race/ethnicity.

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2 MLM models are suggested, but will only be carried out if the previous model results find a significant level of variance.
Means-as-outcomes Regression: used to establish the relationship between IMPACT (level 2) and the individual-level outcome technology implementation.

Non-randomly varying slopes regression: Used as a multi-level model to establish the (moderated) relationship between IMPACT, professional development, and technology implementation.

Non-randomly varying slopes regression: Used to establish the (moderated) relationship between technology infrastructure and technology implementation, when accounting for the effects of home Internet access, home computer access, and number of years teaching.

Results

In the multilevel modeling framework, individual variability is represented through a 2-level hierarchical model (Hawkins, Guo, Hill, Battin-Pearson & Abbot, 2001). At Level 1, each person’s variability (technology implementation) is represented by an intercept and slope that become the outcome variables in a Level 2 model in which they may depend on person-level characteristics (e.g. self-reported professional development participation, self-reported perceptions of technical infrastructure, and race/ethnicity) (Hawkins et al., 2001). Multilevel modeling is frequently used to model relationships using nested data. Because estimates of both between-organization (school) and within-organization (teacher) variability are possible with multilevel models (Lee and Bryk, 1989), conclusions regarding the variability between organizations and within people can be made.
**Model 1: Fully unconditional Model**

It is recommended to conduct a preliminary analysis to ensure that there is sufficient variability at Level 1 and Level 2 to warrant continuation with analyses (e.g. Nezlek, 2001; Raudenbush & Bryk, 2002). This preliminary analyses is termed a fully unconditional model (also referred to as a null model), in which no term other than the intercept is included at any level (Curran, 200; Nezlek, 2001). The resulting interclass coefficient (ICC) from the unconditional model are presented as a percent, partitioning the variance in the dependent variable that is due to between-group vs. within-group variability. In addition, significant intercepts indicate that there is sufficient variability at Level 1 and Level 2 to move forward with analyses.

In this study, the fully unconditional model will allow us to answer the following research questions:

- Is there a significant between-group effect on technology implementation?
- How much of the variance in technology implementation is due to between-school differences?

Results from this analysis indicated that 16% of the variability in technology implementation was between organizations ($\tau_{00} = 1109, z = 2.62, p < .01$) and 84% was within people ($\sigma^2 = 0.5873, z = 15.86, p < .001$) (refer to Table 2). Therefore, the fully unconditional model indicated that there was sufficient variability for further analyses. (refer to table 3 for all subsequent professional development results.)
**Professional Development Model**

Model 2: One-way ANCOVA with Professional Development as a Predictor

Level 1: \( \text{Implementation}_{it} = \beta_{0it} + \beta_{1it}(\text{Professional development}) + \beta_{2it}(\text{Race/ethnicity}) + r_{it} \)

Level 2: \( \beta_{0i} = \gamma_{00} + u_{oi} \)
\[ \beta_{0i} = \gamma_{10} \]

The one-way ANCOVA model allows the researcher to determine the relationship between the dependent variable (technology implementation) and the level-1 (i.e. teacher-level) predictors. Similar to a regression analysis, the Greek letters represent the values of coefficients related to the target variables (e.g. the intercept and slope). In Level 1, the intercept, \( \beta_{0it} \), is defined as the expected level of technology implementation for person \( i \). The professional development slope, \( \beta_{1i} \), is the expected change in technology implementation associated with professional development. The error term, \( r_{it} \), represents a unique effect associated with person \( i \) (i.e. how much the individual fluctuates around the mean). The individual intercepts (\( \beta_{0i} \)) and slopes (\( \beta_{1} \)) become the outcome variables in the Level 2 equations, where the average technology implementation for the sample (i.e. when professional development = 0, when race/ethnicity =0) is represented by \( \gamma_{00} \), the average technology implementation associated with professional development is represented by \( \gamma_{10} \), and the average technology implementation associated with race/ethnicity is represented by \( \gamma_{10} \). The extent to which people vary from the sample average of technology implementation is represented by \( u_{oi} \).
The one-way ANCOVA regression model allows the researcher to examine the relationship between the dependent variable and the teacher-level variables. In this study, the one-way ANCOVA model allows the researcher to examine these research questions:

- Is there a significant and positive relationship between professional development and technology implementation when controlling for race/ethnicity?
- How much of the within-group variance in technology implementation is explained by professional development and race/ethnicity?

There is a significant increase in technology implementation associated with professional development participation ($\gamma_{10}=0.1964$, $t=12.58$, $p<.001$), and 19% of the within-teacher variability in technology implementation was accounted for by professional development. People who report higher professional development participation tend to have higher technology implementation scores. In this model, there was a negative, but non-significant relationship between race/ethnicity and technology implementation.

Model 3: Means-as-Outcomes Regression using IMPACT as a Predictor

Level 1: $\text{Implementation}_{ij} = \beta_{0ij} + r_{ij}$
Level 2: $\beta_{0i} = \gamma_{00} + \gamma_{01}(\text{IMPACT}) + u_{oi}$

The means-as-outcomes regression model allows the researcher to determine the relationship between the dependent variable and the level-2 (i.e. school-level) predictor. In Level 1, the intercept, $\beta_{0ij}$, is defined as the expected level of technology implementation for organization $j$. The comprehensive program (IMPACT) slope, $\beta_{1i}$, is the expected change in technology
implementation associated with IMPACT. The error term, \( r_{it} \), represents a unique effect associated with organization \( j \) (i.e. how much the organization fluctuates around the mean). The organization intercept (\( \beta_{0i} \)) becomes the outcome variable in the Level 2 equation, where the average technology implementation for the sample (i.e. when IMPACT = 0) is represented by \( \gamma_{00} \), and the average technology implementation associated with IMPACT is represented by \( \gamma_{01} \). The extent to which organizations vary from the sample average of technology implementation is represented by \( u_{oi} \).

The means-as-outcomes regression model is used to establish the relationship between IMPACT (level 2) and the individual-level outcome technology implementation. In this study, the research question addressed in the means-as-outcomes regression model is:

- Is there a significant and positive relationship between the comprehensive program (IMPACT) and technology implementation?
- How much of the between-school variance in technology implementation is explained by IMPACT?

In this model, there is a significant increase in technology implementation associated with the comprehensive program IMPACT (\( \gamma_{01} = 0.5121, t = 4.01, p < .001 \)), and 53% of the between-school variability in technology implementation was accounted for by the comprehensive program IMPACT. In this model, organizations involved in the comprehensive program IMPACT tend to have higher technology implementation scores.

Model 4: Non-randomly varying slopes using the interaction between IMPACT and professional development as a predictor.
Level 1: \( y_{it} = \beta_{0it} + \beta_{1it} (\text{Professional development}) + \beta_{2it} (\text{Race/ethnicity}) + r_{ij} \)

Level 2: \( \beta_{0i} = \gamma_{00} + \gamma_{01} (\text{IMPACT}) + u_{oi} \)
\( \beta_{1i} = \gamma_{10} + \gamma_{11} (\text{IMPACT}) \)

The non-randomly varying slopes model allows the researcher to determine the relationship between the dependent variable (technology implementation) and predictors at both level 1 (i.e. school-level) and level 2 (i.e. teacher level). In Level 1, the intercept, \( \beta_{0it} \), is defined as the expected level of technology implementation for person \( i \). The professional development slope, \( \beta_{1i} \), is the expected change in technology implementation associated with professional development and the race/ethnicity slope, \( \beta_{2i} \), is the expected change in technology implementation associated with race/ethnicity. The error term, \( r_{it} \), represents a unique effect associated with person \( i \) (i.e. how much the person fluctuates around the mean). The organization intercept (\( \beta_{0i} \)) and slope (\( \beta_{1i} \)) become the outcome variables in the Level 2 equation, where the average technology implementation for the sample (i.e. when IMPACT = 0,) is represented by \( \gamma_{00} \), and the average technology implementation associated with IMPACT is represented by \( \gamma_{01} \), and the interaction between the comprehensive program IMPACT and professional development is represented by \( \gamma_{11} \). The extent to which organizations vary from the sample average of technology implementation is represented by \( u_{oi} \).

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3 According to Singer (1998), when choosing between the intercepts and slopes as outcomes model and the nonrandomly varying slopes model, one should compare the difference in the \(-2LL\) statistics (Chi square distribution). However, the data for the slopes and intercepts in outcomes model would not converge, which indicates that the model with the slopes constrained results in a better fit than the model with the slopes free to vary. Therefore, the slope was constrained in subsequent analyses.
The non-randomly varying slopes model allows the researcher to examine the cross-level effects, when including both level 1 (school-level) and level-2 (teacher-level) predictors in the model. The research question addressed in the non-randomly varying slopes model is:

- Does the comprehensive program IMPACT significantly and positively moderate the relationship between professional development and technology implementation?
- How much variance in technology implementation is due to the interaction between IMPACT (school level) and professional development (individual level) variables?

In this model, people with high professional development scores tended to report higher levels of technology implementation ($\gamma_{10} = 0.1847, t=8.35, p<.001$). As in the previous model, race was not significantly associated with technology implementation ($\gamma_{20} = -0.09039, t=-1.09, p=.27$). Unlike the previous model, there were no significant main effects of the comprehensive program on technology implementation ($\gamma_{01}= 0.02160, t=0.20, p=.84$). There was no significant interaction between professional development and the comprehensive program IMPACT.

*Technical Infrastructure*

**Model 1: Fully unconditional model**

The fully unconditional model is the same for both professional development and technical infrastructure, as the dependent variable, technology implementation, is the only variable entered in this model (Refer to Table 4 for all subsequent technical infrastructure results).
Model 2: One-way ANCOVA with Technical Infrastructure and Race/ethnicity as Predictors

Level 1: $\text{Implementation}_{it} = \beta_{0it} + \beta_{1it}(\text{Infrastructure}) + \beta_{2it}(\text{Race/ethnicity}) + r_{it}$

Level 2: $\beta_{0i} = \gamma_{00} + u_{oi}$  
$\beta_{0i} = \gamma_{10}$

The one-way ANCOVA model allows the researcher to determine the relationship between the dependent variable (technology implementation) and the level-1 (i.e. teacher-level) predictors. Similar to a regression analysis, the Greek letters represent the values of coefficients related to the target variables (e.g. the intercept and slope). In Level 1, the intercept, $\beta_{0it}$, is defined as the expected level of technology implementation for person $i$. The technical infrastructure slope, $\beta_{1}$, is the expected change in technology implementation associated with technical infrastructure. The error term, $r_{it}$, represents a unique effect associated with person $i$ (i.e. how much the individual fluctuates around the mean). The individual intercepts ($\beta_{0i}$) and slopes ($\beta_{1}$) become the outcome variables in the Level 2 equations, where the average technology implementation for the sample (i.e. when technical infrastructure = 0, when race/ethnicity = 0) is represented by $\gamma_{00}$, the average technology implementation associated with professional development is represented by $\gamma_{10}$, and the average technology implementation associated with race/ethnicity is represented by $\gamma_{10}$. The extent to which people vary from the sample average of technology implementation is represented by $u_{oi}$. 
The one-way ANCOVA regression model allows the researcher to examine the relationship between the dependent variable and the teacher-level variables. In this study, the one-way ANCOVA model allows the researcher to examine these research questions:

- Is there a significant and positive relationship between technical infrastructure and technology implementation when controlling for race/ethnicity?
- How much of the within-group variance in technology implementation is explained by technical infrastructure and race/ethnicity?

In this model, on average, there is a negative, but non-significant change in technology implementation associated with technical infrastructure ($\gamma_{10}=-0.006119$, $t=0.13$, $p=.90$), and 0% of the within-teacher variability in technology implementation was accounted for by technical infrastructure. Likewise, there was a positive but non-significant relationship between race/ethnicity and technology implementation ($\gamma_{20}=-0.1450$, $t=-1.43$, $p=.15$).

Model 3: Means-as-Outcomes Regression using IMPACT as a Predictor (same as above)
The means-as-outcomes regression model outcome for technical infrastructure is the same as that used for the professional development model.

Model 4: Intercepts and Slopes as Outcomes (Non-randomly Varying Slopes) using the interaction between IMPACT and technical infrastructure as predictors.

Level 1: $
\text{Implementation}_{ij} = \beta_{0it} + \beta_{1it}(\text{Infrastructure}) + \beta_{2it}(\text{Race/ethnicity}) + r_{ij}$

Level 2: $\beta_{0i} = \gamma_{00} + \gamma_{01}(\text{IMPACT}) + u_{oi}$
$\beta_{1i} = \gamma_{10} + \gamma_{11}(\text{IMPACT})$
The nonrandomly varying slopes model allows the researcher to determine the relationship between the dependent variable (technology implementation) and predictors at both level 1 (i.e. school-level) and level 2 (i.e. teacher level). In Level 1, the intercept, $\beta_{0it}$, is defined as the expected level of technology implementation for person $i$. The technical infrastructure slope, $\beta_{1i}$, is the expected change in technology implementation associated with professional development and the race/ethnicity slope, $\beta_{2i}$, is the expected change in technology implementation associated with race/ethnicity. The error term, $r_{it}$, represents a unique effect associated with person $i$ (i.e. how much the person fluctuates around the mean). The organization intercept ($\beta_{0i}$) and slope ($\beta_{1i}$) become the outcome variables in the Level 2 equation, where the average technology implementation for the sample (i.e. when IMPACT = 0) is represented by $\gamma_{00}$, the average technology implementation associated with IMPACT is represented by $\gamma_{01}$, and the interaction between the comprehensive program IMPACT and technical infrastructure is represented by $\gamma_{11}$. The extent to which organizations vary from the sample average of technology implementation is represented by $u_{oi}$.

- Does the comprehensive program IMPACT significantly and positively moderate the relationship between technical infrastructure and technology implementation, when race/ethnicity is included in the model?

---

4 According to Singer (1998), when choosing between the intercepts and slopes as outcomes model and the nonrandomly varying slopes model, one should compare the difference in the –2LL statistics (Chi square distribution). However, the data for the slopes and intercepts in outcomes model would not converge, which indicates that the model with the slopes constrained results in a better fit than the model with the slopes free to vary. Therefore, the slope was constrained in subsequent analyses.
• How much variance in technology implementation is due to the interaction between IMPACT (school level) and technical infrastructure (individual level) variables, when race/ethnicity is included in the model?

As in the previous model, race was not significantly associated with technology implementation ($\gamma_{20} = -0.1832$, $t=-1.93$, $p=.06$). In this model, there was a significant and negative main effect between technical infrastructure and technology implementation ($\gamma_{10} = -0.1933$, $t=4.69$, $p=.001$). There was a significant main effect of the comprehensive program (IMPACT) on technology implementation ($\gamma_{01} = 0.6356$, $t=4.69$, $p=<.001$). There was a significant interaction between technical infrastructure and the comprehensive program IMPACT ($\gamma_{11} = -0.2665$, $t=2.71$, $p<.001$). This means that the relationship between technical infrastructure and technology implementation varies depending on the level of IMPACT. In IMPACT schools, the relationship between technical infrastructure and technology implementation is significant and positive and in non-IMPACT schools the relationship between technical infrastructure and technology implementation is significant and negative (see Figure 4). This finding suggests that, the IMPACT program has an effect on the way technology is used in the classroom. This model accounted for 75% of the between-school variability and 2% of the within-organization variability. Figure 6 provides a graphical representation of the interaction between the comprehensive program IMPACT and technical infrastructure as it relates to technology implementation.
Discussion

The purpose of this study was to examine the effect of professional development and technology infrastructure on teacher technology implementation within the context of North Carolina Title I schools participating in a comprehensive program for technology. In general, the results indicate that both predictors influence implementation, one through a direct effect, the other through an interaction effect. The findings from this study reinforce our first hypothesis that professional development has a significant and positive relationship with technology implementation, even after controlling for race/ethnicity. While we did not find a significant interaction effect between professional development and technology implementation, results from the analysis indicate that professional development is an important and powerful teacher-level predictor in schools before and after controlling for a comprehensive program, IMPACT. The professional development measure in this study focuses primarily on how to implement technology using the constructivist approach. Thus, researchers designing professional development courses may want to consider focusing both on technology skill development and incorporating a constructivist framework into classroom technology use in order to increase the level of classroom technology implementation.

Technical infrastructure had a significant interaction with IMPACT after controlling for race/ethnicity as a covariate. This finding indicates that when the comprehensive program (IMPACT) is entered as a level-2 moderator, the relationship between technical infrastructure and technology implementation becomes positive and significant. In other words, when technical infrastructure is combined with a multi-component comprehensive
program, it can be a powerful predictor of technology implementation, explaining 75% of the between-school variance.

Another way to discuss the results is that the effect of technical infrastructure on implementation was different for impact versus non-impact schools. Within impact schools, there was a positive relationship between technical infrastructure and implementation such that the more support perceived, the more likely teachers were to implement. In non-Impact schools there was a negative relationship. The positive interaction effect in IMPACT schools implies that comprehensive programs can, in fact, have a synergistic effect, heightening the impact of one component through the presence of other components. This finding reinforces the notion that using a multi-component approach may be more effective than incorporating only one component, alone (West, 1998).

While the purpose of this research was to determine if there were any technology implementation differences between IMPACT schools, the HLM analysis also allows us to examine if there were any teacher-level effects. It is important to note that this study accounted for a sizeable percent of the individual-level variability in implementation. Without including any predictors (Model 1), 84% of the variability in technology implementation is due to individual-level variability. This finding indicates that, while large-scale programs may have an effect on classroom activity, the majority of technology implementation is currently effected by individual-level variables. We attempted to discern some of these potential variables, when we include professional development and technical infrastructure as level 1 variables predicting technology implementation (Model 2 and Model
4). We find that professional development accounts for 19% of the individual level variance (or 23% of the total variance in implementation) while technical infrastructure does not account for any of the variance. Practically speaking, this finding indicates that professional development can have a powerful effect on teacher technology implementation. School systems interested in implementing technology in the classroom should therefore consider allotting funds toward professional development opportunities for teachers.

There are a number of comprehensive school programs, but almost none test the implicit assumptions underlying the program. For example, most comprehensive programs contain multiple components, acting on various levels and various points of the organization, indicating that a multifaceted approach may have a greater synergistic impact on the outcome. This study represents an improvement upon previous research by a.) attempting to examine the cross-level effects of a comprehensive program, b.) discerning the individual versus combined effect of program components on implementation.

Limitations

Sample Size

The analyses in this study were limited by the sample size. In HLM, each level-2 predictor necessitates 20 participants. While this is only a rule of thumb, it certainly lowers the number of school-level variables that can be included in the analysis. It is possible that an interaction effect between professional development and IMPACT did, in fact, exist, but because of the small sample (low power), the probability of a Type II error was higher.
The sample of IMPACT and non-IMPACT schools all came from a population of North Carolina Title I public schools, and were matched as closely as possible according to size, percent minority students, percent students receiving free or reduced lunch, geographic location (urban vs. rural), reading and math scores and thereby limiting the generalizability to other geographic or SES populations. Future research should expand the population to include a national sample of schools with greater variation in geographic region, SES, and reading and math scores in order to corroborate evidence that technical infrastructure and professional development can influence technology implementation across a variety of school settings.

Moreover, future technology intervention programs may want to discern the lowest dose strength required to create a meaningful change in technology implementation. This study, in particular, was confounded by the sizable financial investment provided to program schools. IMPACT schools received $1.5 million across three years in order to increase technology resources and implementation. While this study identifies two influential components of the IMPACT model, the substantial monetary allotment represents an intervention component, in and of itself, which cannot be easily or frequently replicated in other contexts. Hence, any component effects are confounded by the presence of the corroborating financial investment, thereby limiting the generalizability of this study to other schools.

Cross-sectional data and inability to attribute causation
The IMPACT program intervention was longitudinal in design and research on implementation indicates that it often takes up to three years for implementation to actually occur at the school-level (Scheirer, 2003). However, it is unclear how long it takes for teachers to make meaningful and sustained changes to classroom activities. It is possible that the third year represented a trial or incubation period or that teachers were simply testing technology, without fully committing to its ongoing and sustained use. Thus, teachers may have reached only a partial or low implementation point along the continuum to full implementation. Future research should continue evaluation activities during post-award years in order to determine the long-term and sustained impact of a comprehensive technology program.

The data used in this study is cross-sectional, collected during the third year of the grant, thereby limiting our ability to predict causal relationships between variables, also referred to as ambiguous temporal precedence (Shadish, Cook, and Campbell, 2002). Thus, it is not possible to discern, in this study, the direction of the relationship between the dependent and independent variables. In fact, technology use may have a dialectic relationship with technical infrastructure, such that as teachers increase their technology use, they also create a more dense network of communication and demand technical assistance. Likewise, teachers who use technology more frequently may be more likely to pursue available professional development opportunities. Future research should incorporate a longitudinal pre-test post-test design to evaluating and capturing data on the relationship between these program components.
Maturation and History Effects

However, even when incorporating a pre-test post-test design, there are threats to internal validity that are difficult to ascertain or track. For example, teachers in this study may have undergone maturation during the course of the three-year grant, an issue that is particularly salient for new teachers. The measures in the STNA examine, not only technology-related activities, but also the constructivist approach to teaching. It is possible that, as teachers become more comfortable in the classroom, they are more willing and able to incorporate a constructivist approach to teaching, thereby confounding the influence of the program components. Likewise, as mentioned in the methods section of this paper, selection may be a threat to internal validity, in that the schools that were selected to be part of IMPACT may have differed from non-IMPACT schools from the onset of the intervention.

The cross-sectional data was collected during two different time points. Data from the STNA was collected from IMPACT schools during Fall of 2005 and data was collected from non-IMPACT schools during Spring of 2005. Given this timelag, it is highly possible that intervention and comparison teachers differed in their responses to the measures simply due to the time of year that the measure was disseminated. For example, the beginning of the school year is a time in which students are new and curriculum is undergoing modification to suit the needs of the classroom. Teachers with less experience using technology may be reluctant to incorporate a new technology at the start of the year, but as courses become routine, may be more likely to find new and innovative means to incorporate technology into curriculum. Future studies should disseminate measures to both intervention and comparison
schools at the same time, as well as include a longitudinal data collection process for this measure.

Moreover, while researchers made every attempt to track any historical events that could have influenced technology implementation, it is possible that another external event triggered the increase in technology implementation. For example, it is possible that secular trends in technology software, hardware, and implementation exposed participants to active ingredients prior to or during the course of the IMPACT intervention. The confounding effect of secular trends has been well documented in health behavior research such as tobacco prevention programs, wherein tobacco quit rates were influenced by the rise in national campaigns to increase tobacco health awareness (Thrasher, Niederdeppe, Farrelly, Davis, Ribisl, Haviland, 2004).

Community-based participatory research (CBPR) nature of IMPACT intervention

The IMPACT program was an intentionally ‘flexible’ program, which allowed each school to tailor the intervention to best serve their school community. For example, schools were allowed to purchase different equipment and set different strategic goals and aims for the use of technology. Moreover, teachers were allowed to tailor how they used technology in their classroom to reach classroom objectives. While CBPR is a practical approach to technology implementation in varied school settings which can provide great contributions to the local school communities, it can lead to inherent differences in the type and level of technology implementation. While the differences themselves are not necessarily a limitation, CBPR requires greater levels of monitoring and evaluation to ensure that there are
not pattern biases across the organizations and variables of interest. While the IMPACT evaluators attempted to track the variations across institutions (e.g. obtaining lists of equipment purchased in each school), it is not possible to monitor every potential variation. It is, therefore, important to note that the CBPR nature of the IMPACT program may include unmonitored biases.

Compensatory Equalization

Compensatory equalization occurs when members of the control group receive aspects of the treatment during the measurement process. In this study, members of the control schools were aware of the IMPACT program and wanted to be part of the original treatment program. Despite their assignment to the control group, the control schools received professional development for constructivist use of technology. In some cases, the control schools actually received the professional development from the treatment schools, representing cross contamination. Despite the control schools’ receipt of professional development, this study supports the notion that the treatment schools received higher levels or doses of the IMPACT program components (including professional development). Moreover, schools do not exist in a vacuum, and it is likely (if not guaranteed) that all schools will receive some level of professional development or program component activities. Future studies, however, should consider tracking cross-contamination or the control groups’ exposure to treatment activities in order to understand the effect of the bias, and whether this bias differs among control schools.

Program Adaptation
The IMPACT program was created using a flexible approach (i.e. the program was designed to adapt and change according to the needs of the school). Hence, it is possible that the program components evaluated in year 3 were markedly different in years 1 and 2. Future research should incorporate process measures that would allow researchers to track changes in the program over time. For example, one of the program components was to create an advisory board, whose primary purpose is to create strategic goals and strategies. It is possible that this advisory board changed over the course of the three years, along with the focus of the work they were conducting. Without tracking this, it is difficult to discern how the different comprehensive program components took effect.

Measurement Issues

Another limitation of this study is the sole reliance on self-report data to approximate professional development participation, technical infrastructure and technology implementation. As with all self-report data, the results are limited to the perceptions of the individual and cannot fully account for actual behavior. The measures used in this study relied entirely on retrospective recall, which may result in inadvertent “misremembering” or “forgetting” associated with interference (Galotti, 1999). Likewise, teachers may have falsely reported technical infrastructure, professional development and technology implementation due to the social desirability of the measure. It is possible that teachers in both intervention and comparison schools artificially inflated their responses to the STNA in order to enhance their schools’ image, particularly given the competitive market for statewide funding. Despite their involvement in the study, all of the IMPACT and comparison schools were
essentially competing for future statewide funding and this evaluation may have been perceived by the teachers as an influential factor for future funding decisions. One potential solution for future research is to provide comparison schools with the IMPACT funding and model after the evaluation.

In order to ensure a more valid study, future research should triangulate findings using multiple sources of data (e.g. the frequency of technical assistance per teacher, the frequency and depth with which technology is incorporated in the lesson plan, rosters of professional development activities and participation, etc.) Triangulation is a useful and efficient means to reinforce or corroborate findings based on self-report data.

Future Research

In addition to triangulation, there are some simple modifications that could be made to the measures to enhance their validity. Currently, the response options for technology implementation assess the frequency with which teachers implement technology (0=Never, 5=Daily, respectively). While frequency implies a continuous variable, the response options are in a likert-type format. Developers of future iterations of the STNA may want to consider converting the response options to a more ‘traditional’ likert-type format, ranging from strongly agree to strongly disagree, so as to reduce ambiguity about the meaning of the response options and standardize response options across measures.

The technology implementation scale also refers to several dimensions of technology implementation, namely curriculum development, networking/communication, and in-class student-centered use. However, the primary focus in the literature is on using technology for
a student-centered constructivist approach to technology implementation. Future measures may want to narrow the scope of the measure to focus on each of these dimensions more closely, thereby allowing researchers to discern gaps and needs in the classroom.

The professional development measure provided response options as “yes,” “no,” or “I don’t know.” Teachers only chose yes or no for their responses, creating a dummy code for each item. This limits the variability in this scale and reduces the researchers ability to discern differences across groups. Moreover, the professional development scale assesses the teachers’ participation in professional development opportunities with different content foci, such as “online learner-centered teaching strategies,” or “examining ways to involve parents in student learning with technology.” Rather than relying on self-report and retroactive recall, this may have been better assessed through tracking the availability, type and content of professional development opportunities and keeping a log or roster of each school attendees, which would create a closer approximation to the dose strength needed to have an effect on technology implementation.

This study also does not examine or collect data on the level of professional development courses taken in years prior to the intervention, which may have an effect on teachers’ ability and willingness to implement technology. This may be a particularly salient issue for new teachers, whose national accreditation programs must now include courses on incorporating technology into classroom curriculum.

The technical infrastructure measure poses questions about the availability of resources in the school, representing a general rating of schoolwide technical infrastructure.
However, simply because technical infrastructure exists does not necessarily mean that it is utilized by the classroom instructors. Future measures may want to consider included ‘I statements’ in order to examine the extent to which the technical infrastructure is actually reaching the intended targets: teachers and students. Moreover, many of the questions are double-barreled, making it difficult to tease out the gaps or needs in each classroom. While the scale is suitable to the purposes of this study, a true needs assessment survey should be able to discern individual and classroom needs.

Despite these measurement issues, professional development and technical infrastructure were significantly correlated to technology implementation and explained a sizable portion of the between-group variance. Given the size of the effect using measures with such complications and measurement pitfalls, it would be interesting to examine the effects of these program components using more valid measures.

**Strengths**

Despite the limitations of the research, there are several strengths to this research study. First, this study represents an action-research approach to understanding and evaluating technology implementation in k-12 classroom settings. The majority of research on school technology implementation is performed in pre-service teacher classrooms, which do not always contain the same types of contextual variables as in-school classroom settings. One of the most widely cited school technology implementation studies, Apple Classrooms of Tomorrow, examined teacher and student computer use over a period of 13 years. Research on this widescale program focused on process as opposed to outcomes and does not
provide a clear outline of the program components, dose strength, or intended outcomes of the study (Means, 1998). Moreover, the ACOT study, along with the majority of educational technology implementation studies, is limited to anecdotal and descriptive statistics. The research provided in this thesis represents an improvement upon previous research by offering an outline of the program components, providing a model of the proposed hypothesis, and examining these relationships using advanced quantitative hypothesis testing techniques.

While the design was limited to posttest only, there was an action research element that tried to feedback information. During the course of the three-year grant, the evaluators and program designers realized the importance of introducing a measure to evaluate the program components more explicitly, which could be used to inform this research as well as future studies. The use of this measure in the third year of the study represents an attempt to improve the research evaluation and include an iterative real-world action research approach to evaluation and data collection.

Moreover, previous research in the field of school technology implementation has focused primarily on qualitative or anecdotal evidence, making it difficult to generalize outside of the sample. This research builds upon the qualitative research conducted by previous researchers and a quantitative methodological approach to examining a comprehensive schoolwide program. The study includes both intervention and comparison groups as a means to reduce the effect of some of the aforementioned threats to internal validity, and to improve measurement error associated with case study research.
The quantitative research studies on technology implementation in classroom setting often do not report their statistical analyses, do not adequately describe components of the research program or intervention, do not acknowledge or examine the nested quality of the data, and are frequently limited to descriptive or frequency data. This study contributes the literature by providing an outline of the HLM analyses conducted, incorporating a nested model approach that takes into account the nested structure of the data, provides a detailed description of each program component, and expands beyond frequency analysis to present both individual and school-level effects.

Implications

Professional development and technical infrastructure can have an important and meaningful effect on technology implementation. There are several potential implications of this research study. First, the focus on constructivist pedagogy as a means to augment technology implementation is a major trend in the educational technology literature. The measures utilized in this study incorporate the constructivist pedagogical approach into their assessment. Given the ongoing changes in technology software development and the potential for rapid and exponential improvements in technology, it is important that the groundwork for educational policy and recommendations focus not only on technology, but on the underlying teaching approach that helps to make classroom technology use effective. The focus on constructivist pedagogy may provide teachers with long-lasting and sustainable classroom skills that will endure despite changes in technological trends.
This research study attempts to discern the effects of key program components on technology implementation. In accord with Wests’ (1993) research on comprehensive programs, it is often difficult, if not at times impossible, to tease out the effect of individual component versus the synergistic effect of multi-component interventions. This research study attempts to examine the varying school-level and individual level effects that individual components versus comprehensive programs may have on implementation. This study provides the groundwork for future technology implementation programs. It found that professional development has a significant impact on implementation. Likewise, when technology infrastructure is provided alongside a multi-component intervention approach, it can have a powerful impact on teacher technology implementation. Finally, both predictor variables (professional development, in particular) are highly mutable variables and can be modified and adapted to fit the requirements of the setting as well as the teachers.
References


Brush, T., Glazewski, K., Rutowski, K., Berg, K., Stromfers., C., Van Nest., M., Stock, L., and Sutton, J., 2003), Preparing Tomorrows Teachers to Use Technology (PT3) grant @ ASU Project. Educational Technology, Research and Development, 51(1), 51-72


http://www.census.gov/ipc/www/usinterimproj/


## TECHNOLOGY IMPLEMENTATION

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<tr>
<td>0 = Never</td>
<td>1 = Once Per Grading Period</td>
<td>2 = Monthly</td>
<td>3 = Weekly</td>
<td>4 = Daily</td>
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</table>

In my classroom….

1. I consult publications, online journals, or other resources to identify research-based practices in teaching with technology. 
   - 0
   - 1
   - 2
   - 3
   - 4

2. I identify, locate, and evaluate technology resources (e.g., websites). 
   - 0
   - 1
   - 2
   - 3
   - 4

3. I apply performance-based student assessment to technology enhanced lessons (e.g., student portfolios, student presentations). 
   - 0
   - 1
   - 2
   - 3
   - 4

4. I use technology regularly to collect and analyze student assessment data. 
   - 0
   - 1
   - 2
   - 3
   - 4

5. My lessons include technology-enhanced, learner-centered teaching strategies (e.g., project-based learning). 
   - 0
   - 1
   - 2
   - 3
   - 4

6. I apply policies and practices to enhance online security and safety. 
   - 0
   - 1
   - 2
   - 3
   - 4

7. I use technology to support and increase teacher productivity. 
   - 0
   - 1
   - 2
   - 3
   - 4

8. I use technology to increase my access to professional development resources. 
   - 0
   - 1
   - 2
   - 3
   - 4

9. I use technology to support communication and interaction with parents and the community. 
   - 0
   - 1
   - 2
   - 3
   - 4

10. I use technology to support communication and interaction among staff members. 
    - 0
    - 1
    - 2
    - 3
    - 4

11. My lesson plans refer to both content standards and student technology standards. 
    - 0
    - 1
    - 2
    - 3
    - 4

12. I do research or action research projects, or apply the results of my research to improve technology-enhanced classroom practice. 
    - 0
    - 1
    - 2
    - 3
    - 4

13. I use multiple sources of data to reflect on professional practice and make decisions about the use of technology. 
    - 0
    - 1
    - 2
    - 3
    - 4
<table>
<thead>
<tr>
<th>In My School….</th>
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<tbody>
<tr>
<td>1. An adequate technology base is available (e.g., computers, digital cameras, projection devices, scanners, printers).</td>
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<td>2. Communication systems within the school are adequate (e.g., email among teachers and staff, network drives to upload lesson plans and grades to the main office).</td>
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<td>3. Systems to communicate with parents and the community are adequate (e.g., e-mail, teacher, and/or school Web pages).</td>
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<td>4. Reliability and speed of connections to the external Internet, online databases and resources, etc., are adequate.</td>
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<td>5. Adequate access to technical support is available (e.g., to troubleshoot hardware or software problems, maintain systems</td>
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<td>6. Adequate staffing is readily available in library media coordinator and/or media assistant positions</td>
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<tr>
<td>7. Adequate staffing is readily available in technology facilitator and/or technology assistant positions</td>
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<tr>
<td>1. I participated in professional development opportunities, examining research-based practices in technology-enhanced classrooms</td>
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<td>2. I participated in professional development opportunities examining identification, location, and evaluation of technology resources (e.g., websites).</td>
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<td>3. I participated in professional development opportunities examining student assessment in technology-enhanced classrooms.</td>
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<td>4. I participated in professional development opportunities examining learner-centered teaching strategies in technology-enhanced classrooms (e.g., project-based or cooperative learning).</td>
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<tr>
<td>5. I participated in professional development opportunities examining online security and safety.</td>
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<tr>
<td>6. I participated in professional development opportunities examining the uses of technology to improve individual teacher productivity.</td>
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<td>7. I participated in professional development opportunities examining ways to involve parents and the community in student learning with technology.</td>
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## Figure 1. IMPACT STNA Data Collection Timeline

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<tbody>
<tr>
<td>IMPACT</td>
<td>X1</td>
<td>X2</td>
<td>O1</td>
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<tr>
<td>Control</td>
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<td>O1</td>
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X<sub>1</sub> = Announcement of IMPACT awards. X<sub>2</sub> = IMPACT resources begin to become available.

* Based on the school calendar year

Modified from Shattuck (2006)
Figure 2. Percent of students receiving free lunch for IMPACT and non-IMPACT schools.
Figure 3. Racial/ethnic student population comparison for IMPACT vs. Non-IMPACT
Figure 4. Cross-level moderation between self-reported teacher technology infrastructure, technology implementation and IMPACT
Figure 5. Cross-level model between IMPACT, technology infrastructure and technology implementation
Figure 6. Interaction between technical infrastructure and the comprehensive program IMPACT
Appendix C

Tables

Table 1. Correlations

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
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<td>1. Gender</td>
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<tr>
<td>2. Number of Years Teaching</td>
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<td>.044</td>
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<td>4. Home computer access</td>
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<td>.007</td>
<td>.045</td>
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<td>5. Home Internet access</td>
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<td>-.048</td>
<td>.075</td>
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<td>-.016</td>
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<td>7. Infrastructure</td>
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<td>.106*</td>
<td>.231**</td>
<td>-.001</td>
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<td>.275**</td>
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<td>8. IMPACT_comparison</td>
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<td>.121*</td>
<td>-.106*</td>
<td>-.087</td>
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<td>9. Implementation</td>
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<td>-.049</td>
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<td>-.008</td>
<td>.549**</td>
<td>152**</td>
<td>.314**</td>
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*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).
Table 2. Descriptive Statistics

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<tr>
<th>Variable</th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>S.D</th>
<th>Skew</th>
<th>Kurtosis</th>
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<td>.500</td>
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Table 3. HLM analysis using professional development and race/ethnicity as predictors of technology implementation

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<tr>
<th>Fixed Effects</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
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<td>N=385 teachers N=22 schools</td>
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<tr>
<td><strong>Implementation level, β₀</strong></td>
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<td>3.3770***</td>
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<td>3.3643***</td>
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<tr>
<td>Intercept, γ₁₀</td>
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<td>R² within organization</td>
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<td>.19</td>
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Note: *p<.05, **p<.01, ***p<.001
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<thead>
<tr>
<th>Fixed Effects</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
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<tr>
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<td>N=22 schools</td>
<td>N=22 schools</td>
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<td>Implementation level, β₀</td>
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<td>Intercept, γ₀₀</td>
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<td>IMPACT, β₀ᵢ</td>
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<td>.53</td>
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<td>R² within-school</td>
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Note: *p<.05, **p<.01, ***p<.001