ABSTRACT

GILCHRIST, PAMELA OLIVIA. Science Teachers' Experiences Adopting Innovations from a Photonics Blended Learning Professional Development Program (PBLTPD). (Under the direction of Dr. Tamara V. Young.)

Spurred by national trends to increase the achievement and skills of students in science, technology, engineering, and mathematics, their pursuit of cognate careers, and degree programs, education reformers are developing approaches to improve K-12 science education through the delivery of innovative, research-based science teacher professional development programs. This qualitative, instrumental case study examines one such program, Photonics Blended Learning Teacher Professional Development (PBLTPD). Guided by Rogers's (2003) attributes of innovation theory, this study analyzes fifteen North Carolina middle and high school teachers' experiences in PBLTPD and explores teachers' decisions to implement the photonics and optics content, inquiry-based strategies, and web-based technology tools introduced in PBLTPD. Semi-structured interviews with participants and archrival program documents were analyzed using the constant comparative approach (Bogdan & Biklen, 2006; Glasser & Strauss, 1967).

The findings revealed that middle and high school teachers who participated in PBLTPD learned new science content knowledge, inquiry-based activities, teaching strategies, collaboration skills, facilitation skills for collaborative classroom instruction; and gained a broad awareness of the advantages and disadvantages of web-based technology strategies. The results show that teachers implemented optics and photonics content and inquiry-based strategies introduced in PBLTPD in their classrooms, professional learning communities, and extracurricular programs more frequently than web-based technology strategies. Their use of web-based technology evolved over time as they implemented it in

informal science activities and through formal settings when school districts' promoted the use of the approach. Based on Rogers's attribute of innovation theory (2003), relative advantage, compatibility, and motivation were prominent factors that facilitated partial or full adoption of PBLTPD innovations. In contrast, complexity, lack of resources, and trialability of the limited or impeded aspects of adoption of the innovations.

The findings suggest that blended learning professional developments can facilitate learning of new science content, pedagogical approaches, and web-based technology strategies to meet the needs of middle and high school science teachers. The results also show that teachers benefit from collaborating with peer teachers, researchers, non-profit, and industry representatives to develop real world, problem-based learning experiences for students. Lastly, to promote both learning and full adoption of innovations presented in science teacher professional development programs, designers of professional developments must not only consider the values and needs of teachers and their social systems, but also take into account the innovation's relative advantages (the economic and social advantages of the innovation); compatibility (congruence of innovation with existing beliefs, past experiences, and potential needs of adopters); complexity (the potential adopters' difficulty in using or understanding the innovation); trialability (opportunities for potential adopters to experiment) and the motivation of teachers.

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Science Teachers' Experiences Adopting Innovations in a Photonics Blended Learning Professional Development Program (PBLTPD)

by
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DEDICATION

To my family.

BIOGRAPHY

Pamela Olivia Gilchrist is a native of Saint Pauls, North Carolina, and is the youngest of ten siblings. Encouraged by her parents Waymon and Harriett Gilchrist, she attended East Carolina University after graduating from high school in 1993. As a North Carolina Teaching Fellow, she completed her Bachelors of Science degree in Middle Grades Education with a Science and Social Studies minor in 1997. For five years she taught seventh grade science, coached basketball and softball, served in various school leadership positions, and pursued a Masters of Education in Instructional Technology at East Carolina University. While teaching at Wellcome Middle School, she worked as a leadership facilitator for three years and coordinated the first science outreach program for underrepresented minority students offered through the Center of Science, Mathematics and Technology at East Carolina University.

In 2002, as a visiting international faculty ambassador in the United Kingdom, she taught science and information communication technology to students in grades 6-11. A year later, she moved to Farnham, United Kingdom, and served as the assistant department head of the Information Communication and Technology Department at All Hallows Catholic and Six Form College. In this position, she not only taught students about technology, she also managed staff, the implementation of curriculum schemes, and the vertical alignment of the technology curriculum between the primary and secondary schools. In addition, to fulfill her graduate school requirements, she analyzed curricular and global workforce trends of technology in the United States and United Kingdom.

In 2004 she returned to the United States to teach eighth grade earth and environmental science for one year in the Charlotte-Mecklenburg School System before acquiring a STEM Program Director position at The Science House of North Carolina State University. From 2005 to the present, the author designs and manages state, federally, and privately-funded science, technology, engineering, and mathematics (STEM) programs for students and teachers from across the state of North Carolina in partnership with scientists, engineers, and business leaders.

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CHAPTER ONE: INTRODUCTION

The Third International Mathematics and Science Study (TIMSS) (2011), revealed elementary, middle, and high school students performance in the United States ranged from average, below average, and near or at average levels when compared to their peers in 40 other countries. Additionally, the National Assessment of Education Progress (2012) documented no change in 17-year-old students math and reading scores, while an increase in math and reading scores for 4th and 8th grade. Approximately 65% of 8th grade students' science scores slightly improved from 150-152 at or above level, 32% performed at proficient level, and 2% of students performed at the advanced level. Also, the Program for International Student Assessment (PISA) report show mathematics scores dropped from 487 to 481, science scores dropped from 502 to 497 resulting in the American rankings dropping from 24th to 29th in math, 19th to 22nd in science, and from 10th to 20th in reading (OECD, 2013). These trends suggest students possess merely adequate knowledge, skills, and dispositions required to survive in higher education, the workplace, and our global society (Robertshaw, Leary, Walker, Bloxham, and Recker, 2008). At the same time, the number of jobs in science, technology, engineering and mathematics (STEM) in the U.S. will increase 34% by 2018 (National Science Board, 2010). As such, there is a gap between the need for STEM professionals and the percent of students prepared to pursue a STEM career. With only 22% of high school graduates prepared to meet college enrollment requirements and pursue STEM careers compared to international students in the United States pursuing STEM degrees, there is a substantial need to prepare and encourage U.S. students to pursue STEM careers (Darlings-Hammond, 2006; National Academy of Engineering, 2005; National Center of Education Statistics, 2010; United States Department of Education, 2010).

To address the projected gap, the Department of Education, the National Science Foundation (NSF), and the Bill and Melinda Gates Foundation have funded basic and applied research initiatives to increase and diversify the STEM pipeline by equipping teachers with research-based strategies that will prepare students for STEM careers. In 2010, for example, President Obama's American Recovery and Reinvestment Act appropriated $141.6 billion to equip 21st century learning classrooms, laboratories, and libraries to improve teacher quality, raise student achievement in low-performing schools and STEM integration. In fact, improving teacher quality, raising student achievement in low-performing schools, and STEM integration were priorities in the Race to the Top (RTTT) and Investing in Innovation (I3) initiatives.

With increasing fiscal resources being dedicated to funding education reforms like RTTT and I3 in a milieu where policymakers want to focus on cost effectiveness, it has become increasingly important to determine what STEM reforms are bringing about desired outcomes. Notably, how are STEM reform efforts improving teacher quality and leading to effective integration of STEM content in classrooms. Subsequently, this study examines teachers' experiences in Photonics Blended Learning Teacher Professional Development (PBLTPD), a program designed to prepare science teachers to use inquiry-based instructional methods and technology to teach photonics content in their classrooms. While there are a plethora of studies on professional development programs for science teachers, there are few that focus on photonics and even fewer that have examined the blended learning format for the professional development of science teachers, which PBLTPD does. Although PBLTPD was intentionally designed to incorporate best practices for teacher professional development, little is known about what teachers' experiences were with the program and to what extent teachers actually implemented strategies learned from the program.

Photonics Blended Learning Teacher Professional Development Program History

In 2005, the founding Director of The Science House and a Director of Imhotep Academy (a STEM program) within the College of Sciences at North Carolina State University established the first photonics student outreach program, Photonics Leaders. Photonics is a branch of physics related to light, laser technology, electrical engineering, materials science, and optics (Webster New World College Dictionary, 2010). The goal of the Photonics Leaders program was to prepare underrepresented minority high school students for higher education, in general, and STEM majors, in particular by immersing students in physics content, internships, and college learning experiences. Grounded by the internal and external evaluation reports of Photonics Leaders and empirical research, the Photonics Leaders II (PL2) program was established to improve science teachers' knowledge of physics and technology (National Science Foundation Information and Technology Experiences for Students and Teachers Annual Report, 2008). The primary purpose of PL2 was "to cultivate a world class and broadly inclusive science and engineering workforce; and to expand the scientific literacy of all citizens" (NSF ITEST Solicitation, 2008). This hybrid year-round science and technology-based program sought to expand underrepresented minority sophomore and junior students' awareness of STEM careers, requisite STEM courses, and information technology (IT) competencies by explicitly incorporating teachers and parents. PL2's program's priorities were recruitment and preparation of underrepresented minority high school students for STEM careers, transformation of teachers' and parents' perceptions of how to prepare students for STEM fields, and the dissemination of curriculum products and findings to broader audiences. To facilitate student success and teacher change, the program model incorporated STEM activities and partnerships with scientists and engineers from academia, government, industry, education, and community settings into its program format. The current study focuses on the teacher professional development component of the Photonics Leaders II project, PBLTPD.

Photonics Blended Learning Teacher Professional Development Program (PBLTPD)

PBLTPD is an intensive hybrid (face-to-face and online) program for middle and high school teachers. PBLTPD's objectives are:

1. To introduce and model instructional strategies for effectively teaching photonics content, promoting awareness of STEM careers, and preparing students for the global workforce;
2. To enhance teachers skills, knowledge, and behaviors toward teaching physics to all students, especially under-represented minority students; and
3. To document changes in teachers' classroom practices that impact students' STEM outcomes.

The program format consists of: (a) a face-to-face learning intervention comprised of an inquiry, internship, and technology component, (b) an eight month implementation component which included teachers developing an implementation plan, implementing lessons, and reflecting on the learning experience, and (c) an online follow-up component for participants to reflect upon their learning experiences and learn new photonics problem-based learning curriculum. Each program component was purposefully designed to introduce participants to physics content, inquiry-based instruction, web-based technology tools, and STEM careers. Participants were required to complete all parts of the workshop to receive a $500 stipend and to provide feedback on the impact of program interventions. In three years, the program provided professional development to 57 teachers from 30 counties and five states, North Carolina, Maryland, South Carolina, New Hampshire, and Virginia (Gilchrist & Bowles, 2011).

Professional Development for Teachers

The literature on the professional development (PD) of teachers reveals several key features of effective PD for teachers (Garet, Porter, Desimone, Birman, & Yoon, 2001). Generally, the research suggests the teachers need to know more content, how to teach the content, and what tools to teach content; it also shows the traditional methods for delivering professional development has fallen short in meeting these needs (Chung Wei, Darling-Hammond, & Adamson, 2010; Garet et al., 2001; School and Staffing Survey, 2000, 2004, 2008; Shulman, 1986). PBLTPD was intentionally designed to address these deficiencies and others described in the literature from three different disciplines: a) teacher education (teachers in general and science teachers in particular), b) information technology education, and c) adult education (Darling-Hammond, c2006; Loucks-Horsely, Stiles, Mundry, Love, & Hewson, 2009; Zepeda, 1994).

Purpose of the Study

Using Rogers's (2003) diffusion of innovation theory (RDT), this study examines science teachers' learning experiences with PBLTPD and their decisions to implement components of PBLTPD. The research questions guiding this study are:

1. What are teachers' experiences in the Photonics Blended Learning Teacher Professional Development program?
2. How do teachers implement innovations from the Photonics Blended Learning Teacher Professional Development?
    a. How do participants implement photonics concepts?
    b. How do participants implement inquiry-based approaches?
    c. How do participants implement web-based technologies?
3. What facilitates or impedes science teachers' implementation of Photonics Blended Learning Teacher Professional Development innovations?

Theoretical Framework

The process by which science teachers choose to integrate a new idea, program or approach into their classroom can be examined through Rogers's diffusion of innovation theory (Rogers, 2003). This framework provides an approach for investigating how participants make sense of the professional development experience and the consequences of that experience for future classroom experiences (Ferguson, 2007). Rogers (2003) described an innovation as a new idea, practice, or object that is perceived as new by an individual or other unit of adoption (p. 12). In this study, the innovations are physics content, inquiry-based/constructivist instructional approaches, web-based learning tools, and a hybrid-learning environment. According to Rogers (2003), uncertainty obstructs adoption of innovations. So, uncertainty must be reduced to facilitate adoption. By participating in PBLTPD, where teachers interact with the innovations and learn about the advantages and disadvantages associated with the innovation, it was hypothesized that uncertainty could be reduced. Specifically, uncertainty could be reduced by teachers' engaging in interpersonal communications through different communication channels—in the case of PBLTPD, the workshop environment for teacher learning and discourse; tours of research laboratories, interaction with experts in the field. On-site implementation planning, integration at local school site and online sessions also should facilitate diffusion because new information, ideas and strategies are communicated over channels to members in different social systems.

Briefly, the innovation decision process is comprised of five stages: knowledge, persuasion, decision, implementation, and confirmation (Rogers, 2003). Generally, these stages occur in a time-ordered process and are influenced by characteristics of the innovation. Using the first three stages of this model as a framework allows me to assess how teachers first learned about PBLTPD, what persuaded them to participate in the workshop, and what factors led them to decide to implement or not implement the research-based strategies in their classroom, or other settings.

In the persuasion stage, the potential adopters of innovations consider the relative advantages, compatibility, observability, trialability, and complexity of an innovation. During the persuasion stage, the adopter becomes "more physiologically involved with the innovation, develops a favorable or unfavorable attitude, and anticipates present and future use of innovation before overtly displaying a behavior to try it or not" (Rogers, 2003, p.175). The decision to adopt is influenced by the perspective adopter's assessment of the innovation with evaluation information compiled from personal experiences and peer opinions. Information is used to reduce uncertainties about the innovation. By outlining the relative advantages (the economic and social advantages of the innovation); compatibility of the innovation with existing beliefs, past experiences and potential needs of adopters; complexity (the potential adopters' difficulty in using or understanding the innovation); trialability (opportunities for potential adopters to experiment with the innovation); and observability (visible results or use in social system), the adopter decides to adopt or reject an innovation. The fourth stage, implementation, provides a lens for examining teachers' experiences using the innovations presented in PBLTPD. The fifth stage, confirmation, addresses why teachers decide to continue or not continue to teach or use PBLTPD content, inquiry-based strategies, and web-based technologies in their classroom. Generally, using Rogers's diffusion of innovation decision process will allow me to gain insight about how the attributes of the different innovations that comprise PBLTPD influenced their adoption after completing the workshop.

Overview of Research Design

A qualitative, instrumental case study design was used to examine the experiences of 15 middle and high school science teachers in PBLTPD and their implementation of innovations presented in the program. The teachers taught at public, charter, and alternative schools representing schools districts in nine North Carolina rural and urban counties that represent Tier 1, 2, and 3 economically distressed areas. According to Patton, the case study approach enables the researcher to investigate the why and how of decision making, not just where, what, and when (2001). Yin (2003) describes a case study as an "empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and context are not clearly evident" (p. 13). For this study, the instrumental case study approach was selected to understand teachers' experience in PBLTPD program and their implementation of the components post-intervention.

A semi-structured interview protocol was used to interview teachers on the telephone to gain insight about how teachers' decisions to adopt or reject an innovation introduced in PBLTPD. Interviews, on average, lasted about 45 minutes. Program documents, implementation reflections, Elluminate session recordings, and program report data were examined as well. The data were coded using a constant comparative method to identify categories that correspond to the research questions (Glasser & Strauss, 1967; Strauss and Corbin, 1990).

Significance of Study

This study contributes to the theoretical and empirical literature on professional development of science teachers in several ways. First, because this study examines different innovations—new content, inquiry-based/constructivist strategies, and integration of Web 2.0 tools—and is grounded in Rogers's (2003) diffusion of innovation theory, this study can expand our understanding of how attributes of the innovations influence teachers' use of specific innovations. Second, because this study examines the simultaneous adoption of multiple innovations, this study draws our attention towards understanding the interplay of characteristics of different innovations on adoption. Third, this study contributes to our understanding of the usefulness of a specific type of professional development designed to attend to science teachers' instructional needs with photonics content, Web 2.0 technology, and inquiry processes. Thus providing information about the efficacy of PBLTPD to bring about specific outcomes that provide information about our return on investment—a particular concern during a time with limited fiscal resources and a focus on "what works" in education.

Lastly, this study expands our understanding of the use of the blended learning workshop format to educate science teachers. With technology transforming the way people learn, think, and live in our society, schools are integrating more technology-supported courses with professional development models to address specific learning goals for schools (Means, Toyama, Murphy, Bakia, & Jones, 2010; Picciano & Seeman, 2007; Voogt, 2010). This increase in the use of technology to deliver PD has led researchers to investigate how technology may enhance teachers' pedagogy, technology, and content knowledge in a way to impact students' learning and achievement and how the pairing of face-to-face and online environments or purely online learning environments may meet the professional development needs of adult learners (Irving, 2005; Mishra & Koehler, 2006, 2008; Voogt, 2010).

According to Picciano and Seeman (2008), online education has entered a mature phase of practice at the university level, while the elementary and secondary schools are in the infancy phase. School districts and federal agencies are exploring the advantages and disadvantages of fully online and blended learning practices (Means et al., 2010; Picciano & Seeman, 2008), and research has shown that the connection between technology, content, and student learning in classrooms is shaped by teachers' knowledge (Darling-Hammond, 2006; Shane & Charles, 2005); pedagogical beliefs (Huberman, 1983); policy and school context (Zhao, Pugh, Sheldon & Byers, 2002); administrator support; and the need for professional development (Picciano & Seeman, 2007). Despite these advances, little is known about the connection between teacher learning with technology in PD and their use of technology as they apply the content and strategies they learned in the PD. This study examines PBLTPD, a program delivered face-to-face and by web-based technology, and a key goal is to examine to what extent technology-supported deliveries and activities of PBLTPD inspired teachers' integration of web-based tools in their classrooms. Insights gained will allow us to better understand how teaching and learning with technology in PD may influence teachers' adoption of technology in their classrooms.

With this delivery method gaining popularity, it is imperative to provide insight to designers and implementers of hybrid PD programs about the utility of the method with science educators. In doing so, we ensure that we can meet demands for improved science instruction with the goals of increasing student achievement and interest in STEM.

Limitations

This study is not without limitations. A case study approach is used to examine teachers' experiences in a blended learning teacher professional development program. As with any case study, this study is bound by context and provides information only related to those in the study and this specific professional development program. Another limitation of the study is related to my role as the researcher. I was the creator and director of the Photonics Blended Learning Teacher Professional Development. To address this potential limitation, I kept a personal reflection journal to document my reflections to minimize my research bias. Additionally, much of the data are self-reported. I presume that participants' self-reported information reflect actual experiences with PBLTPD and implementation of its components. Lastly, participation in PBLTPD and study were voluntary, so the participants may represent a motivated population. This possible selection bias is discussed in Chapter Four.

Definition of Terms

Several key terms that require definition are presented below:

Asynchronous learning. A student-centered teaching method that uses online learning resources to facilitate information sharing outside the constraints of time and place among a network of people (Mayadas, 1997).

Blended learning. The thoughtful merging of face-to-face and online learning experiences (Bersin, 2004), which includes two models: mixed, in which online meetings replace a significant portion of FTF instruction, or adjunct, in which online meetings supplement a traditional course (Ho & Burniske, 2005). A blended course involves 25% to 50% of the program activities (i.e., lectures, field trips, leadership sessions) in an environment guided by the instructor that may include synchronous and asynchronous discussions as well as quizzes, visualizations, group work, presentations, and orientations for program activities (Lin, 2008). Hybrid learning and blended learning will be used interchangeably in this study.

Content knowledge. Knowledge of the subject matter that is to be learned or taught (Mishra & Koehler, 2006).

Compatibility. The degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters (Rogers, 2003, p. 15).

Complexity. The degree to which an innovation is perceived as relatively difficult to understand and use (Rogers, 2003, p. 15).

Early adopters. A person within the social system who is regarded as an opinion leader in the system (Rogers, 2003; p. 283).

Early majority. Individuals who adopt innovations before the average member of the social systems and serve as important link in the diffusion process (Rogers, 2003, p. 283).

Elluminate live. An online conferencing system embedded with the following features: synchronous chat, video, whiteboard, graphic slide presentation, application sharing, polling, and emoticon responses (Blackboard, 2013)

Inquiry-based instruction. A student-centered pedagogy that uses purposeful, extended investigations set in the context of real-world problems as both a means of increasing student capacities and as a feedback loop for increasing teachers' insight into student thought processes (Supovitiz, Mayer, & Kahle 2000, p. 332).

Innovation. A new idea, practice, or object perceived as new by an individual or other unit of adoption (Rogers, 2003; p. 12).

Innovativeness. The degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a system (Rogers, 2003, p. 22).

Innovators. The gatekeepers who bring an innovation in from outside of the system (Rogers, 2003).

Laggards. Individuals with a traditional view of innovation and most the benefits of a new idea (Rogers, 2003, p. 295).

Late Majority. The one-third of all members of the social system who wait until most of their peers adopt the innovation and possess a skeptical view of innovations (Rogers, 2003, p. 284).

Observability. The degree to which the results of an innovation are visible to others (Rogers, 2003, p. 16)

Pedagogical content knowledge (PCK). The blending of content and pedagogy into understanding how particular aspects of subject matter is organized, represented, and adapted to the diverse interests and abilities of learners and is presented for instruction (Shulman, 1986).

Pedagogical knowledge. A deep knowledge of processes and practices or methods of teaching and learning, how it encompasses educational purposes, values, and aims (Mishra and Koehler, 2006).

Pedagogical orientations. Teachers' curriculum goals and intentions in their classroom pertaining to the teacher role and student role (Law, 2008).

Professional development. The development of a person in his or her professional and educational role (Villegas-Reimers, 2003).

Photonics. The scientific study or application of electromagnetic energy whose basic unit is the photon, incorporating optics, laser technology, electrical engineering, materials science, and information storage and processing (American Heritage, 4th edition http://www.wordnik.com/words/photonics).

Rate of Adoption. The relative speed an innovation is adopted by members of a social system (Rogers, 2003, p. 221).

Relative Advantage. The degree to which an innovation is perceived as being better than the idea it supersedes (Rogers, 2003, p. 16).

Technological content knowledge. Knowledge related to technology and content are being reciprocally related (Mishra & Koehler, 2006).

Technology pedagogical content knowledge. Knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and knowing how teaching might change as a result of using particular technologies (Mishra & Koehler, 2006).

Technology pedagogical content knowledge-web. The knowledge or capacity to identify appropriate online learning activities for a course and the practice of appropriate pedagogies to support online activities (Lee & Tsai, 2010).

Tier 1. Economic Distressed County - the 40 most economic distressed counties in North Carolina (Rural Economic Development Center, Incorporated, 2014.

Tier 2 Economic Distressed. The next 40 economic distressed counties Tier 2 and the 20 least distressed as Tier 3 (Rural Economic Development Center, Incorporated, 2014). (http://www.ncruralcenter.org/index.php?option=com_content&view=article&id=399&Itemid=125

Tier 3 Economic Distressed. The 20 least distressed counties (Rural Economic Development Center, Incorporated, 2014).

Trialability. The degree to which an innovation may be experimented with on a limited basis (Rogers, 2003, p. 16).

Overview of Study

Chapter One points out that there is a gap between the number of U.S. students prepared to pursue STEM careers and the anticipated growth in STEM careers in the United States. This chapter also described how one particular program, PBLTPD, was designed to address this gap of improving students' STEM knowledge by enhancing science teachers' knowledge of photonics, increasing their effective use of inquiry-based/constructivist strategies, and developing teachers' knowledge of Web 2.0 tools in their classrooms. Chapter One also explained the purpose of this study was to describe teachers' experiences in PBLTPD and their implementation of the innovations presented in the program in order to provide insight about how to improve PBLTPD program in particular, and hybrid science professional development program, in general. Chapter Two reviews the research on the components of the PBLTLD model, science teacher professional development, blended learning, and Rogers's (2003) diffusion of innovation theory. Chapter Three outlines the methodology of this study with particular attention to the research paradigm used to answer the research questions and the procedures for data collection and analysis organized by research questions and themes that emerge. Chapter Four describes the findings; Chapter Five summarizes the key findings, presents both the theoretical and practical implications of the results as well as makes recommendations for directions for future research.

CHAPTER TWO: LITERATURE REVIEW

This chapter reviews the research questions articulated in Chapter One and then provides an overview of the theoretical and empirical research related to the research questions. Specifically, this chapter explains the development and key components of the Photonics Blended Learning Teacher Professional Development (PBLTPD) program. It also includes a description of Rogers's diffusion of innovation theory, the framework guiding this study's analysis, and reviews the literature on professional development for in-service teachers. To conclude this chapter, a historical overview of blended learning research with adult learners and a summary of the chapter are presented.

Research Questions

The primary purpose of this study is to examine teachers' experiences with PBLTPD. Insights from the findings can be used to improve the program and enhance our understanding of PBLTPD, in particular, and provide insight about hybrid PD for science teachers, in general. The research questions guiding this study are:

1. What are teachers' experiences in the Photonics Blended Learning Teacher Professional Development program?
2. How do teachers implement innovations from the Photonics Blended Learning Teacher Professional Development?
   a. How do participants implement photonics concepts?
   b. How do participants implement inquiry-based approaches?
   c. How do participants implement web-based technologies?

3. What facilitates or impedes science teachers' implementation of Photonics Blended Learning Teacher Professional Development innovations?

Photonics Blended Learning Teacher Professional Development Program (PBLTPD)

In 2005, the National Science Foundation's Innovative Experiences for Students and Teachers (ITEST) program solicitation sought out proposals for initiatives that would:

> develop, implement, study, and evaluate interventions that encourage K-12 students to develop interest in and to be prepared for careers in the STEM and ICT workforce of the future, to produce research findings that build knowledge about approaches, models, and interventions involving K-12-aged children and teachers that are most likely to increase the nation's capacity and innovation in the STEM and ICT workforce of the future, and to equip teachers with the resources to ensure that their students consider choosing and are prepared to enter the STEM and ICT workforce of the future.

In response to the NSF's request for proposals, The Science House at North Carolina State University submitted a proposal and was awarded grant funding for a youth-based Information Technology Experiences for Students and Teachers (ITEST) program, Photonics Leaders. The researchers' goals were to expose students to advanced physics and mathematics content, internships, and college learning endeavors to prepare school-age children to be part of the STEM and IT workforce of the future. After three years of collaborating with public school teachers, graduate students, researchers, and industry leaders within the Research Triangle Park, an NSF annual report concluded that there was a need to provide professional learning opportunities to develop teachers' knowledge and awareness of physics, its interdisciplinary STEM applications, and requisite 2lst century competencies required of learners (NSF Annual Report, 2008).

Building on this need for PD in this area and the goals of the NSF ITEST solicitation— "to cultivate a world class and broadly inclusive science and engineering workforce; and to expand the scientific literacy of all citizens" (NSF ITEST Solicitation, 2008)— the Photonics Leaders II (PL2) program was created. PL2 was a hybrid year-round science and information technology program for 60 high school students, 120 parents, and 60 teachers. The primary purpose of PL2 was to engage students, their parents, and teachers in rigorous and innovative learning experiences to develop an awareness of and requisite competencies for emerging STEM and information technology (IT) careers. The program goals were to prepare underrepresented minority high school students for STEM careers and to equip teachers and parents with strategies and resources to engage learners in these disciplines. The program model used to prepare students, teachers, and parents for STEM and IT was based on five components outlined in Figure 2.1.

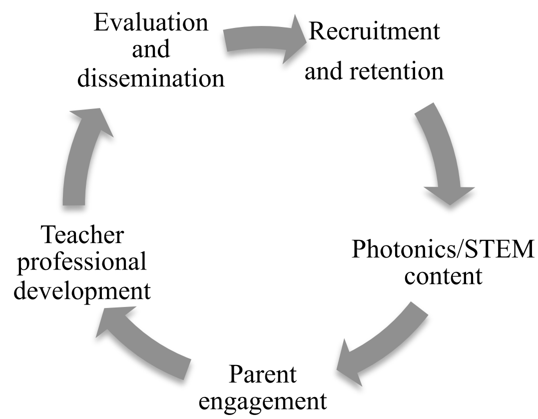

Figure 2.1 Conceptual Model of Photonics Pre-College Program Model.

Each program component is operationalized through one or more of the guiding principles: (a) immersion in traditional and non-traditional hands-on investigations, (b) engagement in a supportive, safe and challenging environment, (c) participation in leadership and professional development training, and (d) integration of professionals from academia, industry, and schools. The program model incorporates synergistic STEM activities and partnerships among participants to foster teacher change that promotes student success in STEM areas. Hilliard-Clark (2008) found these strategies were successful in preparing students for the global workforce. This study focuses on the teacher professional development component of the project, PBLTPD.

PBLTPD Program Overview

PBLTPD teacher workshop was an intensive face-to-face and online program for middle and high school teachers. The 44+ contact hour program consisted of an immersive learning intervention (three days), classroom implementation (6 to 8 months), and online follow-up experience (two days) for participants. The program interventions occurred over five phases: inquiry, internship, technology, implementation, and online follow-up. Each phase was purposefully designed to expose participants to physics content, inquiry-based pedagogical strategies, and web-based technology tools. PBLTPD's objectives were to:

1. To introduce and model instructional strategies for effectively teaching photonics content, promoting awareness of STEM careers, and preparing students for the global workforce;
2. To enhance teachers' skills, knowledge, and behaviors toward teaching physics to all students, especially under-represented minority students; and
3. To document changes in teachers' classroom practices that impact students' STEM outcomes.

PBLTPD, a small-scale professional development design for science teachers integrated Darling-Hammond's (2006) elements for effective teacher professional development. Table 2.1 outlines PBLTPD program strategies were aligned with Darling-Hammond's components to establish an active and reflective learning environment for teachers to interact as learners and professionals in their professional development program and their classroom to lead to new teaching behaviors (Hilliard-Clark, 2008).

Table 2.1

Elements of Effective Teacher Professional Development and PBLTPD Design Strategy

Number		***PBLTPD* Design Strategy**
1	Engage teachers in practical tasks and provide opportunities to observe, assess, and reflect on the new practices	Teacher engagement in inquiry hands-on activities in learning labs with peers, with research scientists, completing daily reflections, implementation plans, and assessments. Laboratory tours and practicum in Component 1, 2, and 3.
2	Be participant driven and grounded in inquiry, reflection, and experimentation	Hands-on activities/orientations in face-to-face and online component (i.e., build spectroscope, polarizer, create holograms, parallel and series circuit activities, fiber optics hands-on activities), problem-based learning problem analysis activity and presentation in Elluminate, e-group discussions and reflections on instructional strategy in Component 1, 2, 3, 4 and 5.
3	Be collaborative and involve the sharing of knowledge	Group and individual work, creation of implementation plans and discourses with middle school and high school teachers. Presentation of implementation activities, discourse with staff, researchers, and fellow teachers in Component 1, 2, 3, 4, and 5.
4	Directly connect to the work of teachers and their students.	Implementation of plans into classroom and school, curriculum piloting and year-round job with student program in Components 4 and 5.
5	Be sustained, on-going and intensive	Extended community of practice of discourse through Moodle, Elluminate, access to Elluminate coordinator and project staff, and continual learning of constructivists' approaches in live follow-up session over six months in Components 4 and 5.
7	Provide support through modeling, coaching, and the collective solving of problems	Project model and support collective solving of problems (i.e., how to arrange tours with scientists, login into Moodle, Elluminate, learning environment interfaces) in Components 4 and 5).
8	Be connected to other aspects of school change (Darling-Hammond, 2006)	Support national STEM goals, encourage presentation of materials to administrative staff and colleagues, participation in student program component, time to develop leadership skills as an educator in Phases 1, 2, 4 and 5 (Gilchrist, Hilliard-Clark, & Bowles, 2010).

Note: Adapted from Darling-Hammond (2006)

PBLTPD was developed from empirical evidence on improving school science education programs; in particular: science teachers' content knowledge (Darling-Hammond, Chung Wei, Andree, Richardson & Orphanos, 2009; School and Staffing Survey, 2000, 2004, 2008), inquiry-based instruction (Colburn, 2003; Shulman, 1986), technological pedagogical content knowledge (Mishra & Koehler, 2000), classroom implementation (Guskey, 2000), and reflection (Borko, 2004; Darling-Hammond, 2006; Shulman, 1986; Tsai and Lee, 2010). Although the program was based on these evidence-based practices, the evaluation of the Photonics Leaders II program indicated a need to further examine teachers' implementation behavior post-intervention and to explore the relationship between participants' implementation and their experiences in PBLTPD (Photonics Annual Report, 2008, 2010, 2011). This study addressed this need. To fully understand teachers' post-intervention practices, it is important to be familiar with the program's main components. The next several sections of this chapter briefly explain PBLTPD's components.

Inquiry-Based Instruction

The American Association for Advancement of Science (AAAS, 1993) and the National Research Council (NRC, 1996, 2000) strongly suggest that teachers use more inquiry-based instruction in their classrooms. Indeed, numerous research studies and commission reports recommend using inquiry instruction to improve the delivery of K-12 science, technology, engineering, and mathematics course content (e.g., Bransford, Brown, & Cooking, 1999; Bybee, Taylor, Gardner, Scotter, Powell, Westbrook, & Landes, 2006; Donovan & Bransford, 2005; Llewellyn, 2002; National Commission on Excellence in

Education, 1983; National Commission on Mathematics and Science Teaching, 2000; National Council of Mathematics Teachers, 2000). Examples of inquiry include tasks that cause students to observe and record natural and experimental phenomena, formulate questions, design experiments, analyze data, evaluate data, draw conclusions, and present scientific results (AAAS, 1993). These activities should be centered on student discussion, argumentation and incorporate linking of related ideas and concepts (Biological Sciences Committee on Standards, 1993). To meet the needs of learners, inquiry activities may vary in delivery because they may be teacher-guided, opened-ended or student-guided (Colburn, 2000; NRC, 2000; Schwab 1962).

The inquiry method has been shown to develop students' deeper understanding of science and its application in the real world (Southerland, Gess-Newsome, & Johnston, 2003). Inquiry-based methods also increase students' knowledge and skills better than traditional lecture methods (National Institute of Child Health and Human Development, Early Child Care Research Network, 2005). Though teachers know that these strategies are an effective way of preparing students for academic success, some teachers choose not to implement these approaches into their science classrooms because of concerns about class size, time management and perceptions of students and their achievement (Shapson, Wright, Eason, & Fitzgerald, 1980). Providing teachers opportunities to do, see, and experience learning from the world of the learner provides a basis for teachers to integrate appropriate pedagogical approaches into their classroom (Darling-Hammond & McLaughlin, 1995; Schoen & Hirsch, 2003b). If teachers learn what it is like to learn using inquiry methods from experiencing them, then they will likely integrate inquiry in their classroom setting. Experiential learning also contributes to the development of teachers' pedagogical content knowledge (Shulman, 1986).

So, PBLTPD model provided a participatory learning experience that emphasized active learning from the perspective of a student. Allowing teachers to become familiar with how students learn and interact with peers in an inquiry-based setting provided teachers a frame of reference they could use for future instructional purposes (Darling-Hammond & McLaughlin, 1995; Schoen & Hirsch, 2003b). Specifically, PBLTPD learning environment promoted an active, social-centered, and leaner-centered approach where participants benefited from experimenting with materials and reflecting on learning activities. Also, because change is more likely to be effective and long-lasting if teachers are allowed to build relationships with one another (Barab, Makinister, Moore, Cunningham, & The Inquiry Learning Forum Design Team, 2001), PBLTPD also included activities that required teachers to develop relationships with each other and trust their peers to contribute to the learning experience.

Content Knowledge

For more than 30 years, a plethora of professional development programs initiatives have focused on increasing teachers' content knowledge and skills (Chung Wei, Darling-Hammond, & Adamson, 2010; Darling-Hammond et al., 2009; Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2009). The greatest need for in-service teacher training is content-focused professional development (School and Staffing Survey, 2000, 2004, 2008), because for teachers to be effective they must have confidence in teaching science content before attempting to integrate different pedagogical strategies (Shulman, 1986). Furthermore, many high school and middle school teachers lack an understanding of light, force, and motion concepts, yet there have been only a limited number of workshops that focus on physical science and physics content for high school teachers (Krall, Christopher, & Atwood, 2009). Thus, an important goal of PBLTPD design model was to introduce middle school and high school teachers to the physics of light content, its ubiquitous applications, and its content connections. Through a hybrid format, PBLTPD introduced teachers to the physics of light content that is often not provided in continuing education opportunities at local schools for teachers (Hodapp, Hehn, & Hein, 2009; Krall, Christopher, & Atwood, 2009). While PBLTPD model focused mainly on light and optics, it also incorporated laboratory tours and field experiences with experts in physics, engineering, and technology—an experience often viewed as one of the essential elements in preparing teachers for 21st century schools, yet one that is not commonly offered through teacher professional development (National Academy of Science, 1996). Also, because PBLTPD is offered in a blended learning format, this study provides insight into how using the hybrid platform relates to development of teachers' content knowledge about the physics of light.

Pedagogical Content Knowledge

Although content knowledge is an essential component of effective teaching, there are other types of knowledge that play an important role in teacher efficacy. In his seminal work, Shulman (1987) reasoned that teachers lack a strong command of content and pedagogy knowledge. His work indicated that teachers need to not only learn and understand subject matter, which he terms content, and employ different teaching and learning strategies in the classroom to improve their pedagogical content knowledge (PCK), which "goes beyond the knowledge of matter knowledge per se to the dimension of subject matter knowledge for teaching" (Shulman, 1986, p. 9). PCK comprises teachers' knowledge of subject matter representation and their knowledge of students' learning difficulties, and conceptions. As such, PBLTPD intentionally aimed to foster not only science teachers' content knowledge, but their PCK as well.

Technological Pedagogical Content Knowledge – Web (TPCK-Web)

Positing that teachers need to develop their knowledge of how to integrate technology in their instruction to develop their technological pedagogical content knowledge (TPCK) for effective teaching in a technology-enhanced environment, Koehler and Mishra (2005) added technology to Shulman's (1986) pedagogical content knowledge framework. Koehler and Mishra (2005) define technological knowledge (TK) as teachers' knowledge about technology (such as digital video or computers) and technological content knowledge (TCK*)* as teachers' knowledge of applying the features and advantages of technology to the subject matter. TPCK extends pedagogical content knowledge by connecting technology, pedagogy, and teacher's craft knowledge about both subject matter and technology devices to support student-learning.

Lee and Tsai (2010) contend that technological pedagogical content knowledge approaches alone might not be sufficient for providing adequate information to improve teacher preparation and professional development when Web 2.0 tools are integrated into instruction. With the availability of web-based tools and advances in web-based instruction to support teaching and learning, these technologies provide new ways for teachers to learn and acquire information, develop a pedagogical skill, and teach. Indeed web-based instruction has gained recognition as a strategy that provides learners with a distant, interactive, individualized, and inquiry-based learning environment (Lee & Tsai, 2010; Miller & Miller, 2005; Relan & Gillani, 1997; Tsai, 2001). It can also promote learners' construction of knowledge and meaningful learning. Therefore, Lee and Tsai (2008) conclude teachers need TPCK-Web when using the Web for teaching and learning.

The TPCK-web framework builds on the ideas of PCK (Shulman, 1986) and TPCK (Mishra & Koehler, 2006) for investigating teacher knowledge, skills and perceptions regarding Web-based instruction. The three components of the framework are web content knowledge (WCK), web pedagogical knowledge (WPK), and web pedagogical content knowledge (WPCK) (Lee & Tsai, 2008). Web covers general knowledge and use of web-related tools and advanced knowledge of web-based communication or interaction tools. Like Shulman (1986), content pertains to knowledge about the subject matter. Pedagogy is knowledge about the process and practice or methods of teaching and learning. Similar to the TPCK framework, web and content are combined to produce an understanding of how to best apply the features and advantages of the web to teach the subject matter. The integration of subject matter knowledge with the appropriate web teaching and learning strategies with students must take into account the varied existence, components, and capabilities of the web's impact in the classroom (Lee and Tsai, 2008). The integration of web, pedagogy, and content relies on a teacher's ability to identify online learning activities and appropriate online pedagogies that fit the course needs and online activities.

Teachers need professional development experiences that model and use web-based tools in content-specific professional development to facilitate the development of teachers' TPCK-W and support the implementation of PBLTPD strategies into the classroom. Thus, a goal of PBLTPD model was to foster teachers' TPCK-Web by exposing them to the photonics content in a web-based environment (that is, the online components of the program). Specifically, teachers were provided a learning platform whereby they could experiment, use, and plan to integrate Web-based approaches into the classroom. This design aimed to increase learners' interactions with the web tools, instructor, content, and peers within the program (Barnett, 2002; Moore, 1989). Overall, veteran teachers' awareness and knowledge of the intricate connections between content, pedagogy, and technology are enhanced by this intentional integration of photonics science content, inquiry-based strategies, and web-based learning tools. Collectively, these components (See Table 2.0) created a learning platform for teachers to learn, use, and plan to integrate web-based research approaches into the classroom. This approach also sought to contribute to the development of science teachers' knowledge of web-based tools and skills.

Table 2.1

Web-based Technology Tools Used in Photonics Blended Teacher Professional Development

	Communication		Medium			Purpose		
Web-based technology	**Synchronous**	**Asynchronous**	**Audio**	**Video**	**Text**	**Content**	**Collaboration**	**Program**
Websites		X	X	X	X	X		
Simulation		X		X	X	X		
Wetpaint	X	X			X	X	X	x
Elluminate	X	X	X	X	X	X	X	x
Breakout Rooms	X		X		X	X	X	
Chat	X				X		X	
Moodle		X	X		X	X	X	X

Lastly, one of the foundational tenets of TPCK and TPCK-web frameworks is that teachers must have the capacity to balance technology, web-based tools, pedagogy, and content knowledge during classroom instruction to effectively further student learning (Koehler & Mishra, 2008; Tsai & Lee, 2010). Tsai and Lee (2008) suggest examining teachers' behaviors, self-efficacy, and web users' self-efficacy pertaining to TPCK-web to improve the design of teacher preparation and professional development programs. This study improves our understanding of the connection between learning content and pedagogy (in this case, inquiry) in a web-enhanced environment and teachers' TPCK-W knowledge, and thus expands our knowledge base of TPCK, TPCK-Web and learning in hybrid environments. Specifically, this study seeks to add to our understanding of how learning in a hybrid professional development (delivered with web-based tools) may improve teachers' effective use of web in the classroom and ultimately student learning.

Reflection

PBLTPD implementation and follow-up components incorporated adult learning principles to support teachers' classroom implementation needs to foster the integration of new practices and teacher reflection. Darling-Hammond and McLaughlin (1995) assert that teacher reflection on their practice is necessary for teachers to integrate new knowledge and beliefs regarding content, pedagogy, and learners into their classroom. Several frameworks have been used to understand teachers' learning, their implementation behaviors, and factors impacting classroom implementation (Guskey, 1986, 2000; Rogers, 1986, 2003; Sandholtz, Ringstaff & Drwyer, 1997). Guskey (1986) suggest one way to measure change in teacher practices is for teachers to document the impact of implementation on student achievement. Sandholtz and colleagues (1997) applied a three-stage process to understand teachers' adoptions of technology into their classroom in the Apple Computers of Tomorrow program. They found that teachers generally move through a survival, mastery, and teacher change plateau when adopting technology (Sandholtz, Ringstaff & Drwyer, 1997).

Reflection also contributes to implementation. Schon (1996) describes teacher reflection as a reflective practice that involves thoughtfully considering one's own experiences while applying knowledge in coached settings. The process by which teachers reflect can occur through one or all three types of reflection: cognitive, critical, and narrative reflection. Cognitive reflection pertains to how a teacher processes information and makes decisions. Research on teachers' cognitive reflection has focused mostly on teachers' reflection of content knowledge, pedagogical methods and theory, curriculum, and learner characteristics (Shulman, 1987). According to Shulman (1987), more research is needed on teachers' reflection on teaching contexts and educational purposes, ends and aims. Critical reflection focuses on the substance that drives teachers' thinking, experiences, goals, values and social implications. Research on critical reflection has shown that it provides a basis for clarifying how teachers think about dilemmas of teaching and its social outcomes in education (Schon, 1996). Narrative reflection refers to a teacher's interpretation of the events that occur in their particular contexts. Research on narrative reflection has provided insight on what motivates teachers' actions and the complexity of their everyday lives. Darling-Hammond and McLaughlin (1995) have documented the need for "teachers to reflect critically on their practice to fashion new knowledge and beliefs about content, pedagogy, and learners" (p. 592). To facilitate the adoption of research-based practices for instructional purposes, PBLTPD provided science teachers opportunities to reflect on their practices, pedagogical beliefs, knowledge, and experiences.

Physics Teacher Professional Development

Teacher professional development is essential in preparing students for the global society. Science education is a fundamental discipline area in education that is often overlooked in the primary and middle school years. Over the past five decades, reform concerns for teacher professional development has changed (Bybee, 2005; Mishra and Koehler, 2006; Next Generation Science Standards, 2013). In the 1950s, the emphasis in science teacher professional development was on attaining teacher-proof curriculum (Bybee, 2005). During the 80's and 90's, more attention was given to integrating inquiry-based instruction in the classroom to develop students' scientific literacy. In the 2000s, the emphasis shifted to technology and now the focus is science and engineering.

This shift in teacher professional development has a focused on systematic change to strengthen the following: "a) scientific literacy for all students, b) new standards for mathematics and science education; and c) professional development for teachers that causes students to think reason, and make discoveries, promote group work, and heterogeneous classrooms (Frechtling, Sharp, Carey, & Vaden-Kiernan, 1995). Loucks-Horsley et al., (2009) found teacher professional development programs were effective when there was evidence of the following elements were documented: a) increase of teacher knowledge, b) provision of teacher renewal and network opportunity, c) increase in leadership and empowerment; d) change in classroom practices; e) increase in student achievement and interest; and f) enhancing minority participation. Considerable debate has occurred regarding the tenets of inquiry-based teaching and learning in science for students.

Optics and photonics teacher workshops are essential, as state and national data has documented the dismal numbers of Physics professionals entering the teaching profession; for example, North Carolina produced only three physics teachers in 2006. One-third of the United States' 23,000 high school Physics teachers enter the field unprepared to teach students. In response to this trend, The National Science Foundation and American Physical Society created the Physics Teacher Coalition in collaboration with numerous colleges and universities to enhance teacher education and in-service programs (http://phystec.org). These programs have trained and worked with secondary teachers mainly with some efforts directed to the lower grade levels. One study suggests modifying curricula for improving optics instructions for high school and college students in teacher-training programs, to enhance their conceptual knowledge of light and vision. Clearly, a need exists to prepare middle and high school teachers to teach optics and photonics concepts. Thus, an important goal of PBLTPD design model was to develop middle and high school teachers' knowledge of physics content, its ubiquitous applications, and its content connections. This study seeks to examine teachers' experiences in PBLTPD.

Researchers have examined several different factors found to contribute to teachers' use or implementation of innovations (e.g., content, pedagogy strategies, and/or technology) in their classroom. Several factors that impact implementation are discussed in this section: teacher efficacy, motivation, concerns, learning style, school context, and professional development structure.

Teacher Efficacy

Teacher beliefs or efficacy direct the enactment of instructional innovations in their classroom (Bandura 1977; Cronin-Jones, 1991; Guskey, 1988). Teacher beliefs include their thoughts about their ability and role in their classroom as well as how their students learn and their students' ability (Bandura, 1997). These beliefs generally impact teachers' attitudes and actions in their classroom. Cronin-Jones (1991) found that teachers' beliefs strongly influenced their curriculum implementation. He recommended providing teachers' opportunities to identify, examine and change existing beliefs about how students learn and their role in a classroom prior to developing curricula or programs to improve teacher implementation of curriculum.

Teacher efficacy research examines teachers' judgments of their capacity to bring about desired outcomes of student engagement and learning in their classroom. Bandura (1977) hypothesized that people develop a generalized expectancy about action-outcome contingencies based upon life experiences and develop beliefs about their own coping abilities. These behaviors are generally implemented based on teachers' self-efficacy and belief that they can perform or produce a desired outcome. Riggs and Enoch (1990) have argued that efficacy is a significant factor contributing to science teachers' reluctance to teach science, and how efforts must be undertaken to increase teachers' awareness of efficacy and its implications for subject matter knowledge, team teaching, professional development schools, and mentoring programs to improve teachers' beliefs, and attitudes towards teaching science. Ghaith and Yaghi's (1997) research examined the relationship among teachers' efficacy, experience, and attitudes towards implementing instructional innovations and found that personal teaching efficacy was a strong determinant of teachers' willingness to adopt new practices. Ghaith and Yaghi's (1997) findings also indicated a negative correlation between teacher experience and classroom implementation and no correlation between attitudes and teachers' classroom implementation. The research revealed that measuring teachers' personal and teaching efficacy and working with experienced and inexperienced teachers differently enhanced teacher efficacy and are positively related to teachers' willingness to implement instructional innovations (Guskey, 1987; Stein & Wang, 1988; Ross, 1994).

Teacher Concerns

The Concerns-Based Adoption Model (CBAM) is an instrument used by educational leaders to evaluate innovations and how individuals most affected by change react to implementation of these innovations (Hall & Hord, 1987; Rutherford, Hall & George, 1982; Todd, 1993). Three instruments are used to collect relevant data: Stages of Concerns (*SoC*), Level of Use (LOU), and Innovation Configurations (IC). The most widely used instrument is the *SoC*, which measures teachers' concerns about the innovations they are expected to implement (Hall & Hord, 2001). Hall, Hord, and Rutherford (1987) defined concerns as the thoughts, feelings, and reactions individuals develop towards a new program or innovation relevant to their daily job.

The *SoC* instrument provides a way for assessing seven stages of concerns: awareness, informational, personal, management, consequences, collaboration and refocusing. These seven stages are categorized into four levels: unrelated concerns, self-concerns, task concerns, and impact concerns to capture the types of questions teachers may ask regarding their experience and exposure to the innovation. This instrument may be used to measure teacher concerns before, during, and after the implementation of professional development programs and provide an avenue to integrate the voice of teachers who drive the implementation of instructional strategies. Overall, this information may inform PD developers on how to improve potential implementation.

Researchers employing the CBAM *SoC* instrument have contributed to the understanding of the change process, teachers' needs, implementation of innovations, and program planning to increase the implementation of innovations (Daas, 2010; Donovan, Hartley and Strudler, 2007; Grable, 1997; Vaughn, 2003). Vaughn's (2003) research examined the significance of taking into consideration the in-service teachers' concerns and suggested that successful implementation of new programs depends on teachers' participation and level of comfort; as teachers became more familiar with the innovation, their concerns moved from personal to task and impact concerns. Integrating activities that are specific to the teachers' concerns to alleviate their concerns and promote change through the predictable sequences of *SoC* as teachers become involved with implementing the innovation. Hartley and Strudler (2007) found that urban middle school teachers were more likely to implement one-to-one laptops into their classroom when the professional development activities were aligned with their concerns. They also found that incorporating the teachers' voices into the program reduced uncertainty about the innovation and increased the adoption and implementation of the innovation. Once teachers' personal concerns were met, they tended to have more concerns regarding the management of technology.

Daas (2001) investigated the implementation of instructional innovations in K-8 science classes and found a close connection between classroom implementation by teachers and program implementation by the school district. Using the CBAM *SoC* instrument and an integrative approach to teaching and learning, Dass (2001) analyzed teachers' stages of concern for implementation of constructivist and science-technology-society (STS) approaches.

He found that at the *SoC 0* (awareness) and *SoC 1* (informational) stages, teachers were seeking awareness of constructivists and STS approaches. During the *SoC 0* and *SoC 1* stages, then, teachers deconstructed unfamiliar terminology and expectations, which affected their initial participation. At the *SoC 2* (personal) stage, teachers were concerned with their ability to meet the program requirements of using the constructivists and STS approaches since they were not well-versed in these principles. At the *SoC 3* (management) stage, teachers' concerns dealt with issues of implementation of the innovation regarding organizing and managing time demands, access to resources, and related grade-level team curriculum goal conflicts, while at the *SoC 4* (consequence) stage, teachers were focused on the relevance of the innovation with the students, evaluation of outcomes and changes needed to improve student outcomes. At the *SoC 5* (collaboration) stage, teachers were focused on coordination of successful implementation of approaches between teachers, mainly because some teachers may be resistant to the new approach due to conflict with traditional views of education. Finally, at the *SoC 6* (refocusing) stage, teachers were not expected to reach this stage.

For those who completed implementation and reflected upon their work, reflections included strategies for improving modules and having to find information on their own due to changes they desired to enact. Daas's (2001) research demonstrated that teacher concerns related to classroom implementation are intimately connected to professional development at the district level, and focusing on concerns also brought the voices of science teachers to the forefront.

Appleton and Kindt (1999) acknowledged the importance of teachers' voices when they suggested that more attention be given to what teachers think, feel, and need in order to improve science instruction in their classrooms. Integrating the voices of in-service teachers into the development of professional development programs has been shown to contribute significantly to educational reform in the classroom and more information is needed regarding teachers' experiences in professional development that promotes the implementation of instructional innovations. Spark (1983) and Dass (2010) suggested that in-service teacher professional development has the potential to be the central element of educational reform when designers proactively consider the thoughts, feelings and concerns of participating teachers.

Motivation

Emphasizing the significance and need to more critically study the motivation construct in professional development initiatives, Schieb and Karabenick's (2011) resource guide highlights over 250 resources related to teacher motivation and professional development. The collection of articles focuses on teachers' motivation to participate in a professional development and to apply acquired knowledge and skills to their instructional practices. Scheib and Karabenick (2011) found few research studies that addressed teachers' motivation and perceptions prior to the intervention; these studies tended to focus on motivation and perceptions only during and following the programs. To date, there has not been a systematic attempt to analyze factors that influence teachers' motivation for participating in a professional development, their level of engagement during PD activities, and the degree to which teachers' motivation and engagement in the PD influences their classroom instructions. Such information is needed to identify necessary components of school reform. Alexander (2008) contended that professional development could influence teacher motivation for teaching math and science and attempting new instructional practices. This next section briefly describes a few studies that consider motivation and implementation.

Cavy and Mulloy (2010) investigated the relationship between cognitive and motivational factors and teachers' implementation of an innovative early childhood program. This qualitative study employed Jesus and Len's (2005) integrated model of cognitive-motivational theories, which combines several theories and concepts into a unified model: a) learned helplessness (Seligman, 1975); b) motivational discrepancy theory (Jesus, 1995); c) self-efficacy (Bandura, 1977); and d) intrinsic motivation theory (Deci & Ryan, 2006). By integrating attribution and expectancy factors, the researchers found factors influencing teachers' cognitive-motivational behaviors. The model was used to explain low and high teacher performance. These findings revealed that teachers' cognitive understanding of the program strongly influenced their motivation to implement the intervention. Also, teachers noted that the authentic learning community was motivating; and consistent feedback, support from the program staff, recognition, and financial remuneration would bolster their overall implementation of interventions (Cavy & Mulloy, 2010).

Southerland, Sowell, Blanchard, and Granger (2010) suggested combining pedagogical discontentment and self-efficacy to measure teachers' motivation to change their classroom practices to reflect reform efforts. Pedagogical discontentment is the cognitive conflict that exists when an individual recognizes a mismatch between their science teaching pedagogical goals and classrooms practices. They argue that science educators should value creating dissonance, discontentment, and uncertainty in the early stages of professional development. Southerland et al.'s (2010) research revealed that teachers with moderate to high pedagogical discontentment were more motivated to learn and implement new practices into their classroom to achieve their teaching goals. This information may contribute to understanding whether pedagogical discontentment or cognitive-motivational factors influenced teacher implementation of PBLTPD strategies.

Learning Style

Researchers in the field of learning styles have hypothesized that personality-type preference can have an effect on a learners' assimilation of new knowledge (Kiersey & Bates, 1984). Much work has been done to apply Jung's theory (1972) that investigates the differences in how people perceive information, make decisions, reflect, and act when interacting with others. Myers-Briggs Type Indicator (MBTI) (Briggs and Myers, 1998) is an instrument developed to identify personality types. It organizes personality types into 16 personality type preferences using the scales of extraversion (E), introversion (I), sensing (S), intuition (N), thinking (T), feeling (F), judgment (J), and perception (P). Overbay, Patterson, Vasu, and Grable (2009) examined the relationship between learning style, level of resistance to change, and teacher retention in schools implementing an intensive school-wide technology program and media technology model. They found that middle school teachers with ST (sensing-thinking) and SF (sensing feeling) learning style preferences possessed a high level of resistance to change while teachers with ST learning style were three times more likely to leave their schools compared to teachers with other learning style preferences. The findings of the study suggest that teachers with ST learning styles might need additional support to enable them to adapt to changes within a dynamic environment of a school undergoing an intensive technology reform effort.

Contextual Factors

Darling-Hammond (1998) identified nine contextual factors that influence the design of professional development programs: students, teachers, practice (which refers to curriculum), instruction, assessment, and the learning environment (policies; resources, organization culture), organization structures, history of professional development and parental as well as community factors. Each of the factors can act as a facilitator or barrier for teachers to use strategies introduced in a PD. Both Lambert (1988) and Wade (1989) found that professional development is only moderately effective at bringing about change in schools because they often fail to account for teachers' concerns when planning their professional development, which is similar to findings related to teacher concerns.

Zhao, Pugh, Sheldon, and Byers (2002) examined 11 salient factors that significantly impact the implementation classroom technology innovation integration. Each factor was related to one or more of the following domains: the innovator (the teacher), the innovation, and the context impacting the success of a technology implementation program on the K-12 level. The research revealed that factors that influenced the innovator's implementation were the teachers' (type of teachers needed) technology efficiency, pedagogical compatibility, and social awareness. In reference to the innovation, they found that the implementation of technology was difficult to the extent to which the innovation deviated from organizational culture, dependence on other people, and the school technological resources. Lastly, Zhao et al. (2002) found that context had a strong mediating effect on teacher implementation of an innovation. They noted human infrastructure, technological infrastructure, and social support as particularly salient factors.

Professional Development Format

Teacher professional development programs are essential interventions for improving teacher quality, their pedagogical knowledge, and student achievement (Smith, 2010). They have evolved from providing curriculum kits and resources for science teachers to implement in the classroom to focusing on the development of content knowledge, integrating appropriate pedagogical strategies, and experimenting with technology (Gess-Newsome, Bocher, Menasco & Willis, 2003; Newsome, 2001; Shulman, 1986; Mishra & Koehler (2006); Wallace, Dickerson, Sickle, Tempel, Coffey, & Powell, 2004). These programs are offered to pre-service and in-service teachers through teacher education programs, graduate courses, professional leadership organizations, and collaborative partnerships among schools, industry, and academia (Borko, 2004; Loucks-Horsley, 1999, 2006). They have different formats and impact teachers differently depending upon their unique teaching and learning needs.

For teacher professional development to contribute to teacher quality, it must address teacher certification, content knowledge, pedagogical knowledge, standards alignment, and their adult learning needs (Darling-Hammond & Young, 2002; Educational Testing Service, 2004). According to Darling-Hammond (2003) and Borko (2004), reflective practice and experimentation of new practices provide foundations for transformation of teachers' beliefs, philosophies, and practices. Currently, researchers are investigating the relationship among the strategic integration of content, pedagogy, and technology and standard alignment in traditional face-to-face settings, online, and hybrid platforms to determine the benefits of these professional development models (Means et al., 2010). An effort to provide different professional development opportunities for teachers to learn new strategies may support teachers' professional development needs and improve classroom implementation of new practices.

The duration of professional developments has been found to be an important factor to influence teacher implementation of new practices. Desimone (2009) proposes a short teacher professional development approach to address teacher quality, which incorporates active learning, content knowledge, convenience, and duration for participants. Desimone's (2009) study demonstrated a positive and significant effect on student achievement with intervention durations greater than fourteen hours. Yoon and colleagues (2007) found that professional development programs ranging from 30 to 100 hours over a six to 12 month period produced a positive and significant impact on student achievement gains. Current professional development researchers advocate long-term teacher professional development experiences for teachers to document change in teachers' practices, beliefs, and values. Several studies indicate that change occurs in teachers' practices when they see its impact with their students in addition to alignment with their teaching philosophies and values (Bryan & Atwater, 2002; Guskey, 1996, 2000; Kagan, 1992; Parajes, 1999,).

Rogers's Diffusion of Innovations Theory

The process of adopting new innovations has been studied for over 30 years and has been applied to research in a variety of disciplines including political science, public health, communications, history, economics, technology and education (Dooley, 1999; Stuart, 2000). Rogers's diffusion of innovation theory is one of the most popular adoption models, especially for technology diffusion and adoption (Parisot, 1995; Sherry & Gibson, 2002). Professionals in a number of disciplines from agriculture to marketing have used this theory of innovation of diffusion to increase the adoption of innovative products and practices (Surry, 1997). Its origin is rooted in anthropological research that examined the transfer of technological innovations from society to society (Rogers, 2003). The concepts of culture and the investigation of intercultural diffusion resonate with anthropologists. For example, Wissler's (1914, 1923) study of the diffusion of horses from Spanish Explorers to American Indians in the West and the spread of corn growing from the American Indians to Europeans settlers demonstrates the spread of innovations between societies.

Ryan and Gross's (1943) research with hybrid corn led to the rise of a diffusion theory research framework among rural sociologists whose efforts were directed at transferring new agricultural technologies to farmers. Their work produced a more focused effort among scholars to answer questions regarding variables related to innovativeness, rate of adoption over time, and factors contributing to the speed of adoption; they also noted the significance of the human factor in the adoption of innovations, and their work has influenced research in third world countries and in the education field on American soil.

Mort (1957) applied diffusion theory to school systems and found that local control over school as opposed to federal or state control was related to increases in school innovativeness and that the best predictor for school innovativeness was expenditure per student. Other education diffusion studies include the adoption of kindergarten in the United States (Wollons, 2000a, 2000b) and modern mathematics (Carlston, 1965). For example, the Carlston (1965) study examined the role of opinion leaders in diffusion networks for modern mathematics among school superintendents and found that the initial adopter was too innovative and the adoption of math was delayed until a group of superintendents viewed as opinion leaders adopted the innovation. Wollons' (2000a, 2000b) work examined the spread of kindergarten throughout the world (Poland, Japan, China, & United States) to show how local educators can transfer and reinvent innovations to reflect their national values (2000a, 2000b). Rogers (2003) put forth that the advancement of technology has stimulated and strengthened diffusion theory research in communications, public health, medical and marketing fields. While a limited number of diffusion research studies have occurred in the education field, Rogers's framework is useful for studying participants' decision in PBLTPD program, for it provides a way to examine teachers' experiences and decisions in a program created to introduce innovations to teachers (2003).

Rogers's (2003) diffusion of innovations theory is comprised of four main elements: innovation, communication channels, time, and social systems. Each element contributes to the adoption process.

Innovation

Rogers (2003) described an "innovation as a new idea, practice, or object that is perceived as new by an individual or other unit of adoption" (p. 12). Uncertainty about changes that occur in an individual or a social system as a result of adoption or rejection of an innovation (i.e., consequences that can be desirable, undesirable, direct, indirect, anticipated, and unanticipated) is an obstacle to adoption of innovations. In this study, the innovations presented in PBLTPD are physics content, inquiry-based instruction, web-based learning tools, and the hybrid-learning environment. These innovations were communicated through different channels over time to members of a social system. The overall goal was to reduce the degree of uncertainty towards these innovations by disseminating information about them and providing time to use them in a supportive environment.

Communication Channels

Rogers (2003) explains "diffusion as a very social process that involves interpersonal communication relations" (p.19). Communication is "a process in which participants create and share information with one another in order to reach mutual understanding" (Rogers, 2003, p. 19). Diffusion includes communication channels—mass media and interpersonal communication—about an innovation between two individuals or other units of adoption. A channel may be "localite," in that it is between individuals within a social system or cosmopolite whereby the communication is between an individual and outside sources. Channels are powerful methods for creating and changing strong attitudes held by an individual (Sahin, 2006). In many cases, the interpersonal channels that are "homophilic"—between individuals with similar beliefs, education, and socioeconomic status—may contribute to the adoption of innovations. Of particular interest in this study of the implementation of PBLTPD strategies is whether teachers mention that the implementation of PBLTPD components were influenced by interpersonal channels and if these channels were homophilic in nature.

Time

Rogers (2003) argued that time is generally ignored in behavioral research and the time dimension is a strength in diffusion research. Because this study occurred after teachers have had time to implement PBLTPD components (one to three years), I was able to examine the role of time in rate of adoption.

Social System

Rogers defined a social system as "a set of interrelated units engaged in joint problem solving to accomplish a common goal" (p. 23). Diffusion of innovations takes place in a social system and is influenced by the social structure of the social system. Rogers's definition of structure "is the patterned arrangement of the units in a system" (p.24). Being able to understand the role of teachers' social systems in the adoption of PBLTPD innovations provides more information for designing blended learning professional development for science teachers.

Innovation-Decision Process

Roger (2003) described the innovation-decision process as “information-seeking and information-processing activity where an individual is motivated to reduce uncertainty about the advantages and disadvantages of an innovation” (p. 172). The innovation-decision process is comprised of five stages: knowledge, persuasion, decision, implementation, and confirmation. These stages typically follow a time-ordered sequence. Generally, a person’s decision, in this study, a teacher, to adopt an innovation occurs over time and progresses “from first a knowledge of the innovation” (knowledge stage) “to forming an attitude toward the innovation” (persuasion stage); “to a decision to adopt or reject” (decision stage); “to implementation and reinvention of the new idea” (implementation stage), and to confirmation of this decision (confirmation stage) (p. 161).

The first three stages—knowledge, persuasion, and decision—are important in understanding why someone tries an innovation for the first time and are used in this study to analyze and understand the teacher responses regarding adoption of PBLTPD strategies. Using this model's first three stages as a framework provides information about how a teacher first learns about PBLTPD innovations, what persuades them to participate in the workshop, and what factors led them to decide to try or not try the research-based strategies in their classroom and the student program. The fourth stage, implementation, provides a frame for examining the teachers’ experiences teaching the strategies in their class, a primary focus of this study. The fifth stage, confirmation, addresses the issue of why the teachers decide to continue or not continue to teach or use PBLTPD content, inquiry-based strategies and web-based technologies in their classroom. Overall, this framework provides an approach for examination of how the participants make sense of the professional development experience and the consequences for that experience for future classroom experiences (Ferguson, 2007).

Attributes of Innovations and Rate of Adoption

Being able to understand the application of the innovation-decision process in reducing the uncertainty of an innovation will provide useful information in understanding what worked in PBLTPD and what can be changed to improve model. According to Rogers (2003), “The innovation-decision process is a mechanism for reducing uncertainty” (p. 232). He identified five attributes of innovations that influence their adoption: relative advantage, compatibility, complexity, trialability, and observability. Rogers state “individuals’ perceptions of these characteristics predict the rate of adoption and that 49-87% of variance of rate of adoption of innovations is explained by these factors. Also, the innovation-decision type, communication channels, social system, and change agents could increase the predictability of the rate of adoptions of innovations. Having a better understanding of teachers’ perceptions of PBLTPD components as it relates to these five attributes that influence adoption may provide a deeper understanding of teachers’ decisions to implement, adopt, and reject approaches.

Alternative Diffusion Research Theories

According to Surry (1997), instructional technology-related diffusion research falls in two main philosophical domains: determinist and instrumentalist. Determinists' diffusion studies generally focus on reform and restructuring an organizational environment. It occurs on the macro level. Rogers's diffusion theory falls in the deterministic category. The other category, instrumentalist diffusion research, focuses on increasing the adoption and utilization of a specific product. Hall, Hord, and Rutherford's (1974) Concern Based Adoption Model (CBAM) and Burkman's (1987) User-Oriented Instructional Development (UOID) process are concerned with adopters' use of the innovation on a micro scale. CBAM research examines how the adopters' concerns, particularly teachers, may influence their use of innovations. Burkman's UOID theory proposes analyzing diffusion of innovations by applying a systematic, scientific method, which entails three stages: research, development, and diffusion (DDD). DDD contends that abandoning folklore approaches to diffusion of innovations and using the DDD approach will improve adoption at the adopters' level. Each philosophical domain contributes to understanding the intricate components of diffusion theory from a micro and macro level. Combining the determinists' and instrumentalists' views together to analyze diffusion on the micro and macro level provides a more holistic understanding of how each part of the whole system is related and a better understanding of the innovation, innovator, and social system to improve the overall diffusion process.

Blended Learning Research

Blended learning has enhanced, challenged, and extended teaching and learning experiences of adult learners for more than 50 years (Bersin, 2004; Dede, 2010; Hartman, Dzuiban, & Brophy-Ellison, 2007). First, it stretched industry instructor-led classes by removing the boundaries of time and location. Through training courses, it integrated options for meeting the diverse career advancement needs of professionals (Bersin, 2005). It also challenged traditional methods of teaching and learning by requiring that adult learners and educators use technology hardware, software, and networks in ways that enhanced accessibility, affordability, and educational needs (Bersin, 2004, Picciano & Seeman, 2007). Lastly, it has enhanced the range of teaching and learning approaches with adults through the incorporation of diverse learning modalities, techniques, resources, and tools used for the investigation of educational, societal, medical, and economical problems (Dzuibian, Hartman, & Moskai, 2004; Nagel, 2011; Yeh, 2010).

Researchers have examined different constructs of blended learning (Christensen, 1997; Dzuiban, Hartman, & Moskai, 2004; Picciano & Seeman, 2007). Driscoll's (2002) research, for example, examined different learning strategies for blended learning. Other researchers have investigated the education outcomes of blended learning (Graham, 2005; Sing & Reed, 2001). Christensen (1997) examined the transformative nature of technology on adults within an organization to determine application of technology. Dzuiban, Hartman & Moskai (2004) investigated blended learning's impact in higher education, and Graham

(2005) sought to discover how to best optimize blended-learning environments with the right" learning technologies and the "right" learning for the "right" person at the "right" time.

Decades of research on blended learning have influenced adult learners. During the 1960s, blended learning began within the corporate setting, rapidly infused higher education in the 1980s, and is now gaining considerable ground in the K-12 arena (Bersin, 2004; Graham, 2005; Picciano & Seeman, 2007; Voogt, 2010). Research within these sectors has shown blended learning can be effective with adult learners given certain circumstances, notably the identification of blended learning's advantages, interaction with experts who use the approach, training that presents how to use the environment and strategies, and time to use the environment and plan lessons that incorporate pedagogical, social, managerial, and technological strategies (Kaleta, Skibba, & Joosten, 2007). The next sections will outline how blended learning approaches have been applied to educate adult learners on the corporate and higher education level. It will also identify the benefits and challenges of using blended learning approaches with adults and its potential implications with adult learners in the K-12 level setting.

Corporate

Ongoing, innovative staff development approaches are critical for the survival and profit of a corporation. Research suggests that corporate leaders are constantly investigating capacity building approaches that align with the organization's goals and accommodate adult learners' professional needs, including the integration of a blended format to train employees (Schofield, Australian Centre for Organisational, and Learning*,* 2002; Wall & Ahmed, 2008;

Wu, Chen, & Chiu, (n.d). These findings provide recommendations for designing learning environments for adult learners.

Schofeld et al. (2002), for example, examined eight factors for adult learners to be critical features for providing quality online learning opportunities—flexibility, choice, leadership opportunities, learner autonomy, coaching, collaborative learning experiences, relevance, and cross-discipline learning. In particular, these attributes were found to support adult learners' acquisition of experiences in acquiring new skills and knowledge to meet their professional needs. Wu and his colleagues' (n.d.) work identified eight attributes of e-learning programs that produced change in employees' behavior: quality service, relevant content, high system usability, feedback loops, employee self-efficacy, commitment, performance, and perceived value to the company. Wall and Ahmed's (2008) study of a blended-learning professional development in a construction setting found that the program format contributed to mastery of content. By providing individuals time to practice using skills and knowledge in spaces that support adult learners' autonomy, professional goals, collaborative, social needs, online and blended learning formats benefited the corporation as a whole (Wall & Ahmed, 2008). These factors may have similar impact with science teachers. Aspects of this research concerning adults using a hybrid platform were integrated into PBLTPD's program design: teacher autonomy, flexibility, and reflection to support science teachers' learning experiences.

Higher Education

Many institutions of higher education have adopted the hybrid course model due to its potential to increase student-learning outcomes (Skill & Young, 2002). Within the past 20 years, blended-learning research in higher education has largely comprised implementation and design studies (Lin, 2008; Simpson & Anderson, 2009), examination of the integration of technology innovation (Riffell & Sibbell, 2005), qualitative case studies on teaching and learning (Stacey & Gerbic, 2009), the establishment of community of practices (Smith, Stacey, & Ha, 2009; Thompson & Kanuka, 2009), and student satisfaction enrolled in post-secondary institutions (Amrein-Beardsley, Foulger, & Toth, 2007). Garnham and Kaleta (2002) reported that instructors "almost universally, believe that students learn more in a hybrid format than in a traditional class" (p.2).

Currently, e-learning approaches are placing a greater demand on faculty than traditional teaching approaches at the university level (Hartman, Dzuiban, & Brophy-Ellson, 2007). More and more faculty members are expected to integrate learner-centered approaches rather than didactic approaches. With the increasing frequency and instructional request for technology integration, faculty members are experimenting with how e-learning strategies can address learner-centered needs in their courses (Hartman, Dzuiban, & Brophy-Ellison, 2007). Research in higher education regarding traditional modes of teaching, learning, and research is being redefined by technology (Dede, 2011; Hartman, Dzuiban, & Brphy-Ellison, 2007). Emerging technologies are reshaping the relationship between faculty and students, thus complicating the definition and instructional direction of quality teaching

(Hartman, Dzuiban, & Brophyl-Ellison, 2007). In fact, Jenkins (2006) argued that the gold standard for teaching (i.e., lecturing, face-to-face instruction) will not change but will converge with online instruction (a new media) from grassroots communities who establish models of teaching.

Dzuiban, Hartman, & Moskal (2004) posits that blended learning offers a viable option for higher education to transform its organizational, financial, and educational systems. To transform the higher education landscape, online education in higher education requires innovation, entrepreneurship, and internal change among participating faculty members (Rahman, 2001). Change, however, has not been easy and universities have faced two major implementation issues: 1) how to foster faculty awareness and interest; and 2) how to best prepare faculty to teach hybrid courses (Kaleta, Skibba, and Joosten, 2007). Schifter (2000) examined compensation models and faculty resistance related to online learning environments and found that faculty beliefs about time investment and learning within their courses produced poor implementation. Similar results were reported by other researchers research studies (Keengwe, Kid, & Kyei-Blankson, 2009; Saleh, 2008). More research is needed to understand the adult learning process, their reflections, and use of blended learning in their classroom to consider blended learning implications at the K-12 level.

Elementary and Secondary Education

The increasing presence of blending learning in K-12 teacher professional development programs and classrooms has enhanced our understanding of the advantages and disadvantages of technology integration in schools (Means et al., 2010; Owston et al., 2008; Picciano & Seeman, 2007; Voogt et al., 2005). According to Picciano and Seeman (2007), 95% of the schools in the United States are experimenting with technology and are documenting mixed reviews of its overall impact. Blended learning in schools is approaching 50% because many schools are experimenting alternative delivery methods to address limited course offerings, teacher shortages, alternative school programs, online course weaknesses, and fiscal matters.

Several studies have documented (a) favorable views from administrators and district leaders regarding the use of technology to address school needs; and (b) conflicting findings concerning teacher implementation and their use of technology in the classroom (Owston et al., 2008; Picciano & Seeman, 2008; Voogt et al., 2005; Yeh et al., 2010). For instance, a comparative case study of two blended in-service programs examined the potential of technology to create a "community of practice" among teachers (Voogt et al., 2005). The findings were conflicting, documenting both a promising application with extending a community of practice of educators and barriers in developing collaborative spaces among educators (Voogt et al., 2005). Reynolds et al. (2003) noted that teachers may have difficulty integrating technology tools due to the significant variability added to teaching and learning (Reynolds et al., 2003). Owston et al., (2008) found that a blended learning teacher professional development program had a positive impact on middle school mathematics and science teachers' attitudes, content knowledge, and teachers' motivation. From a situated-design implementation perspective, Owston (2008) noted that blended learning was effective in providing on-the-job training, collaboration with other teachers, moderate change in teacher practices, and a limited effect on student learning. Yeh et al., (2010) found that an experimental blended-learning teacher professional development improved teachers' content knowledge and personal teaching effectiveness, concluding that blended learning and other factors are important mechanisms that contribute to teacher improvement. Specifically, they found meaningful classroom implementation occurred when teachers were allowed to use their expertise and creativity to develop instructional products that address their local school's contextual and cultural needs (Yeh et al., 2010). These experiences connected to teachers' school context and expertise, which improved their content knowledge and teaching effectiveness. Zhao and colleagues (2005) also found instructor involvement to be a strong mediating factor when examining advantages for blended learning over purely online learning in teacher professional development programs with literacy teachers. Schmidt (2013) explored, in a mixed method study, the impact of blended learning in delivering content, using online instruction, videos, discussions, and face-to-face activities on teachers' mathematics and science instruction in grades 4-11. The study revealed that the students and teachers perceived blended learning approaches as beneficial and useful approaches for learning and teaching. There were not strong affects found between learning mathematics and science content and learning management systems. But teachers who for the first time had ever used these web-based tools were planning to continue to use these tools in their classroom. Finally, Berger's (2008) research with 21 physics teachers in a blended learning professional developed examined teachers knowledge integration and use of instructional strategies in a professional development. The findings revealed that teachers' knowledge and practices progressed over time and the format supported the continual growth of progression of high school physics teachers. Overall, these studies show that blended-based PD may bring about desired outcomes to support teachers change and growth as well as provide avenues for teacher discourse, coaching, and feedback activities related to implementation of innovations into their classrooms. These findings provide a basis for PBLTPD to examine the benefits and the blended learning PD with middle and high school teachers.

Summary

In summary, Chapter Two presented a description of the development of PBLTPD model, its goals, and components. This chapter also provided literature on in-service teacher professional development and select factors that may influence teachers' classroom implementation. Additionally, Rogers's diffusion of innovation theory, the framework guiding analysis, is explicated in detail. The chapter concludes with a discussion of blending-learning use with adult learners in corporate, higher education, and K-12 teacher professional development settings. Chapter Three will present the study's methods. It includes a description of qualitative case study and the research design that was used to answer the research questions. The chapter also outlines the data sources and specifies procedures for analysis.

CHAPTER THREE: METHODOLOGY

The purpose of this study is to examine science teachers' learning experiences in PBLTPD, a blended-learning photonics teacher professional development program. Guided by Roger's (2003) diffusion theory, this study also sought to identify factors that contribute to teachers' implementation of innovations presented in PBLTPD. Specifically, this study investigates:

1. What are teachers' experiences in the Photonics Blended Learning Teacher Professional Development program?
2. How do teachers implement innovations from the Photonics Blended Learning Teacher Professional Development?
    a. How do participants implement photonics concepts?
    b. How do participants implement inquiry-based approaches?
    c. How do participants implement web-based technologies?
3. What facilitates or impedes science teachers' implementation of Photonics Blended Learning Teacher Professional Development innovations?

This chapter describes the research paradigm guiding the study's inquiry, data sources, and procedures for analysis. Specifically, it includes a discussion of why a qualitative case study design was selected to understand teachers' learning experiences in the Photonics Blended Learning Teacher Professional Development program (PBLTPD) and their subsequent implementation of components of the program into their classrooms. This chapter also includes details of the purposive sampling method and data sources, including surveys, archival documents, and semi-structured interviews. This chapter concludes with an explanation of the data analysis procedures and steps taken to establish the validity and reliability of the research design.

Design of Study

Qualitative research tenets guide this study's research design. Strauss and Corbin (1990, p.17) describe qualitative research as "any kind of research that produces findings not arrived by means of statistical procedures or other means of quantification." These findings are arrived from the real world setting where the "phenomenon of interest unfold naturally" (Patton, 2001, p.39). According to Bogdan and Biklen (2006) qualitative research is naturalistic, descriptive in nature, processed-oriented, inductive, and meaningful. In qualitative research, the primary role of the researcher is to identify and interpret the reality of the individual (Merriam, 1998). This role requires the researcher to interact within the research space and create rich descriptions of the research context and participants. Data-collection instruments bridge the gap between the individual involved in the study and the researcher (Merriam, 1998).

According to Miles and Huberman (1994), qualitative research allows the researcher "to explicate the ways people in particular settings come to understand, account for, take action, or manage their day to day activities" and "to capture research data on the perceptions of the local actors from the inside (p. 7). To that end, this qualitative study allows the researcher to discern not only the what, where, and when, but also how and why, thus contributing to a rich, contextualized description of participants' experiences (p.7).

Merriam (1998) asserts that qualitative research relies on “the view of reality constructed by individuals interacting with their social worlds” (p. 6). That is, qualitative research methods serve to support the researcher in the analysis and interpretation of individuals’ constructed understanding of their experiences. The qualitative research approach is ideal for understanding teachers’ perspectives of a hybrid PD and for developing an in-depth understanding of their decisions to implement innovations presented in PBLTPD.

The case study method was chosen for this study to develop a deeper understanding of the teachers’ experiences. Patton (2002) asserts that a case study is useful in creating a deeper understanding of particular people, problems, or situations in comprehensive ways (2002). A case study method is used to investigate a contemporary phenomenon within its real context, especially when the boundaries between the phenomenon and context are not clearly evident (Yin, 1994). It is also used to gather an in-depth understanding of human behavior and the reasons that govern such behavior.

Merriam (1998) puts forth that a qualitative case study is a holistic description and analysis of a single instance, phenomenon, or social unit. Case studies are bound systems and are “particularistic,” “descriptive,” and “heuristic” (Merriam, 1998). For instance, they are particularistic because they focus on a particular situation, event, program, or phenomenon (Merriam, 1998). In this study, the particularistic focus is the experience of middle and high school teachers who share a common experience—participation in PBLTPD program, a blended-learning PD for science teachers that introduces teachers to photonics inquiry-based strategies, and web-based technology. Generally, case studies provide a rich, thick description of a phenomenon under study. This study describes in detail science teachers' perceptions of the blended-learning environment and programmatic information. The description consists of a depiction of the context, details about the data sources, which themes occur more or less frequently and, if present, the extent to which the themes differ by different data sources or groupings within a data source (e.g., teachers who are comfortable with photonics content versus teachers who are not comfortable with photonics content).

Lastly, through the course of conducting the current study, insights that I gained have allowed me to make recommendations to improve PBLTPD and also provide information about how to offer effective hybrid PD for science teachers (see Chapter Five).

Stake (1995) identified three types of case studies. They are intrinsic—a research approach used to understand something about a particular case; instrumental—a research approach used to understand something other than the particular case; and collective—a research approach used to understand several individual cases. For this study, the instrumental case study approach was selected to examine teachers' input regarding their experience in PBLTPD program. According to Stake (1995), an instrumental case approach can be used to advance understanding of something other than the particular case (Stake, 2000). The case in this study too is bounded by its context, time, and activity.

Specifically, each teacher participated in the hybrid physics-based program over a 6-8 month period of time during which they were introduced to the same best practices and basic photonics content. They were also provided an opportunity to reflect upon their learning as well as to develop implementation plans for the classroom. The instrumental case study approach is an appropriate and suitable method for it allowed me to provide additional insight related to the teachers' unique learning experiences, their behaviors, and experiences with a central focus on the teachers who were participants.

This case study focus on teachers' adoption or rejection of innovations learned in PBLTPD and contributes to the literature that seeks to understand factors that influence teachers' adoption of innovations as well as ideal design techniques for a hybrid PD workshop. Stake (1995) describes the case as being a secondary interest in an instrumental case because the case plays a supportive role that facilitates the researchers' understanding of the main questions of inquiry. As the researcher, I examined PBLTPD design in depth, scrutinized the context, and detailed its ordinary activities to more fully understand what influenced teachers' innovation-decision process. This case study is atypical in that it uses a blended (face-to-face and online settings) program design created to introduce teachers to photonics content that is not widely introduced to educators, and layers in technology, content, and pedagogical approaches that impact science teachers' daily effectiveness. Photonics is currently an emerging area of content that has pervasively transformed every fiber of our society in fields such as communication, defense, medical, engineering, and science (National Academy of Sciences, 2012). More efforts are needed to develop middle and high school educators' knowledge and awareness of photonics content, inventions, technology environments, and engineering applications. This case provides additional information about one such effort, PBLTPD and teachers experiences with the programs' content, pedagogy, and hybrid design as well as their efforts to implement content and strategies taught in the program.

Sampling Selection and Setting

According to Merriam (1998), "purposeful sampling is based on the assumption that the investigator wants to discover, understand, and gain insight and therefore must select a sample from which the most can be learned" (p. 61). Merriam asserts that a case study has two levels of purposeful sampling: one level pertains to the criteria for selecting the case; other levels involves the pre-established method for selecting information rich cases from your sample.

Site Selection

Using an extreme case sampling approach, the Photonics Blended Learning Teacher Professional Development (PBLTPD) Program was selected as a unit of analysis for its unique design and research-based strategies employed with middle and high school science teachers in North Carolina. In the words of Patton (2002), an extreme case sampling method is used to select cases that are information-rich because they are unusual or special in some way with outstanding successes or notable failures. North Carolina State University PBLTPD program is the first hybrid (face-to-face and online) optics and photonics professional development created in North Carolina for science teachers by The Science House research team. As shared earlier, this hybrid teacher professional development program introduced teachers to photonics content, pedagogical, and technological approaches that could be used to teach photonics.

Sampling Procedures

Patton (2002) suggests studying information-rich cases that may provide information about issues of central importance to your inquiry to produce insight and in-depth generalizations rather than empirical generalizations. For this study, I used the maximum variation sampling method for selecting a wide range of cases to document unique variations that could emerge from different conditions. As Patton (2002) maintains, maximum variation allows the researcher to capture the core experiences and central, shared aspects of impacts of a program. A researcher can maximize variation in a small sample by identifying diverse characteristics or criteria to construct a sample. In this case study, I used specific criteria to select participants from a population of 57 teachers. For this study, the standard criteria were used to select the middle and high school teacher participants:

1) They must have participated in PBLTPD
2) They must have completed a classroom implementation plan
3) They must meet one of the following implementation levels:
    - **Level 1:** Completed the face-to-face training, used strategies with students in their classroom, and participated in the online follow-up component;
    - **Level 2:** Completed the face-to-face training and online follow-up component but **did not** use strategies in their classroom;
    - **Level 3:** Completed the face-to-face training and used strategies with the students in their classroom, but **did not** participate in the online follow-up component

This maximum variation sampling technique has ensured the inclusion of a wide range of cases to strengthen the study's credibility and illustrate differences among the participant subgroups in PBLTPD program (Patton, 1990).

To recruit participants, the entire population of 57 teachers was contacted via email by the researcher and invited to participate in the study. The email letter (see Appendix C) outlined the study's purpose, participation requirements, projected time of the study, and the reason for recruitment to participate in the study. Within one week, I followed up with non-responsive participants by the telephone and via email to recruit participants that met the criteria. A phone call was placed to contact each interested participant and arrange a time for the interview; a follow-up email (see Appendix I) was then sent to each participant to confirm the scheduled time. Data were collected and analyzed until saturation was achieved.

Data Collection

For this study, the research activities followed human subject requirements specified by the North Carolina State University Institutional Review Board (IRB). An IRB application (Appendix A) including the supporting documents: Informed Consent Form (Appendix B), participant email letter (Appendix C) demographic survey (Appendix D), interview protocol (Appendix E) and field notes document (Appendix F) forms were submitted prior to the study for IRB review and received approval. The primary data source was in the form of semi-structured interviews and research journal reflections, while the secondary sources included archival program documents (i.e., teacher reflections, implementation plans, program documents, curriculum materials).

Interviews

According to Kvale (1996), a qualitative research interview is a construction site for knowledge, "an interchange of views between persons conversing about a theme of mutual interest" (p. 14). Patton (1990) explained that the purpose of an interview is for the researcher to obtain "a special kind of information and…to find out what is in or on someone else's mind." Patton (2002) further explained that interviewing uncovers information that cannot be directly observed, such as feelings, beliefs, perspectives, and that "we cannot observe how people have organized their world and meanings they attach to what goes on in the world" (p. 341). Similarly, Merriam (1998) indicates that interviews are necessary to collect information about feelings and behaviors one cannot observe or replicate.

Semi-structured interviews were employed to understand participants' experiences in the blended-learning PD (i.e., benefits, challenges, perception, and action). Participants' names were replaced with a pseudonym on transcripts and printed documents to ensure confidentiality. Interview protocols were used to discover science teachers' experiences with the program and implementation behaviors after their participation in the blended-learning photonics professional development. Questions were intentionally designed to solicit information related to the research questions. According to Bernard (1998), semi-structured interviewing is best to use when the researcher will not get more than one chance to interview someone. I conducted a pilot interview to revise interview questions as needed based upon input from the interviewee from Maryland and to test Blackboard Collaborate. Technical difficulties were confronted during the pilot interview with the voice feature and online connection. So, to prevent technical difficulties with participants, I interviewed participants via the telephone, which also allowed me to accommodate the participants' schedule and diversity in geographical locations.

Prior to the interview, an email was sent to confirm the interview time and outline expectations for participants' prior to the interview, which included: reviewing the study's informed consent form, signing and dating it electronically; and completing the demographic survey which collected information related to participants' years of experiences, discipline specialty, gender, and use of strategies from the program. Participants were also asked to call the conference call number 15 minutes prior to the interview time. I followed up with participants who failed to call at the scheduled interview time and made alternate appointments when needed.

During the interview, I reviewed the informed consent document, asked study participants if they had any questions about the purpose of the study and their rights; and asked if they had completed the demographic survey. Participants who had not completed the demographic survey prior to the interview were allowed time to complete the survey before the interview. Each interview lasted a minimum of 40 minutes and no more than 90 minutes, for an approximate total of 900 minutes. Reflections were taken during the interview to document information regarding participants' answers to the interview protocol and my personal reflections.

All interviews were digitally, audio-recorded and conducted during the last week of May and the first two weeks of June in 2013; transcribed by a hired transcriptionist, and reviewed by me for validity of content prior to analysis.

Archival Documents

According to Merriam (1998), "documentary data are particularly good sources for qualitative case studies because they ground the investigation in the context of the problem being investigated and the analysis of this data lends contextual richness and helps ground the inquiry in the milieu of the writer." Additionally, documents can be used to corroborate and enhance evidence from other sources (Yin, 2003). Documents may include demographic data, reports, archived data, soft or hard copy, videos, journals or government documents. Table 3.1 outlines what archival documents were used and what was learned from these data sources.

Table 3.1

Data Source Table

Data Source	**Number of Documents**	**Date Collected**	**What will be gained?**
Pre-survey registration data	57	January 2009, 2010, 2011	Teachers current classroom needs & teacher ability
Implementation plan	35	March 2009, 2010, 2011	Teacher initial plans of implementation
Inquiry reflection	43	March 2009, 2010, 2011	Feedback about inquiry activities and program context
Implementation reflection	17	April 2009-December 2009 April 2010-December 2010 April 2011- December 2011	Actual implementation self-reported
Internship reflection	54	March 2009, 2010, 2011	Feedback about activity & program context
Technology reflection	53	March 2009, 2012, 2011	Feedback about technology activity & learning experience
Elluminate Powerpoints lessons	3	April 2010, September 2010, April 2011, August 2011	Implementation activities, needs, and reactions to PBL approach
Moodle, Wetpaint, & Wiki	20 20	April 2010 – 2011 February 2009	Program design and activities
Workshop Curriculum, Materials & Resources	70	February 2009- August 2011	Information about content and materials

For this study, a document analysis form (Appendix G) was used to review the following documents: teachers' content and technology reflections (Appendix H) pre-survey registration records (Appendix H), internship reflections (Appendix H), implementation plans (Appendix H), implementation reflections (Appendix H), online documents (Wetpaint & Moodle), session recordings (Elluminate), curriculum materials, and the program annual reports. This information was used to provide contextual information and supplement findings from the interview data.

According to Patton (1990), documents can be used to inform the research context and provide informal insight into participants' thoughts and actions about PBLTPD, their implementation, and adoption of PBLTPD innovations. Each document also contributed to the narrative description of the program. Implementation plans revealed PBLTPD strategies teachers proposed to use in their classroom and any anticipated barriers related to implementation. My goal was to discover what innovations teachers' used in their classroom, concerns they had about initial use, and their perception of the advantages and disadvantages of the hybrid format. Teachers' reflections provided insight about teachers' experiences in PBLTPD, their perceptions of the experience, alignment with instructional objectives, and what they learned from each session. Program documents in Moodle ®, Wetpaint ® and curriculum documents provided detailed information about the program itself. Also, the pre-survey results of PBLTPD program were analyzed to provide information about teachers' perceived professional needs prior to participating in the program.

Data Analysis

The data collection and analysis procedures for this study overlap (Eisenhardt, 2002). In this study, data analysis began as soon I began reviewing documents. A constant comparative method of analysis was employed to identify categories related to this study's research questions using open, axial and selective coding (Glasser & Strauss, 1967; Strauss & Corbin, 1990). All data were analyzed in the *Atlas.ti* ®qualitative data analysis software using two approaches for coding data sources: categories established during analysis (open and axial coding specified by Glaser and Strauss, 1967); and categories established prior to the analysis (in this case, applying codes based on categories specified in Rogers Diffusion of Innovation Theory).

In 1967, Glasser and Strauss described grounded-theory as a qualitative methodology for building theory. Strauss and Corbin (2008) defined grounded theory analysis procedures as a process for examining and interpreting data to elicit meaning, gain an understanding, and develop empirical knowledge. While this study is not based on grounded theory tenets, it employs grounded theory tools for the analysis of this study. In the words of Glasser (2002), grounded theory can serve as a guide for data collection within and outside the study.

First, I employed open coding, an analytical process for identifying concepts, their properties, and dimensions within the data (Strauss & Corbin, 1990). Specifically, as I read the data line-by-line, I looked for recurring ideas and identify categories based on similarities. After open coding, I then identified how the categories were related to each other using axial coding. Then, I employed selective coding which involves selecting a core category and identifying how the different categories relate to the core category.

Whereas this first approach to coding is inductive, the second approach is deductive. The second approach to coding that I used is a priori coding method whereby the codes (see Appendix I) were established in advance based on Rogers's diffusion theory's attributes of innovations. In this instance, I re-read the data line-by-line and apply the predetermined codes to the data.

Descriptive narratives of the categories and quotes from participants were included to provide responses to each of the research questions. Erickson (1998) recommends balancing between the description and interpretation using the following strategies: particular description, general description, and interpretative commentary (as cited in Merriam, 1998, p. 235). Particular descriptions are quotes from people interviewed, field notes, and vignettes of the natural occurrence of a situation. General descriptions are used to provide the reader a frame of reference as to whether the vignettes and quotes are typical of the data as a whole. Interpretative commentary is "necessary to provide a guide to the reader to see the analytic type of the instance is a concrete token. . .and thus points the reader to salient details, and to the meaning-interpretation of the author" (Erickson, 1986, p.152, as quoted in Merriam, 1998, p. 235). Incorporating these strategies to explain the findings allowed for more nuanced and rich descriptions for understanding, meaning, and processes of participants (Denzin & Lincoln, 2003).

Validity and Reliability

Merriam (1998, 2002) asserts that qualitative investigations must be conducted in an ethical manner to ensure validity and reliability (p. 202). In qualitative research, validity is concerned with questions regarding the extent to which the research findings match reality, capture what is really there, and if investigators are observing and measuring what they think they are measuring (Merriam, 1998, 2002, Shenton, 2004). Reliability refers to the extent to which research findings can be replicated (Merriam, 1998; p. 205). This study employed several strategies to ensure validity and reliability: triangulation; rich, thick description; and researchers' reflexivity.

Denzin (1974) identified four types of triangulation: data triangulation, investigator triangulation, theory triangulation, and methodological triangulation. This study used data source triangulation, which involved using different sources, to increase validity (i.e., research findings reflect what is truly occurring in this case). The different data sources included pre-survey data, interviews, and documents. I also used thick, rich descriptions of the teachers' learning experiences in PBLTPD and their classroom implementation. This approach allows the readers into the setting and to discern if the results are dependable and transferable (Shenton, 2004). Using thick descriptions, I presented "detail, context, emotion, and the web of relationships that join people to one another" (as cited in Ponterotto, 2006, p. 540).

Lastly, as the researcher of this study, I critically reflected upon my assumptions, worldview and biases in relationship to this study. Ely noted that "reflexivity in research is built on an acknowledgement of the ideological and historical power dominant forms of inquiry exert over the research and the researched" (as cited in Hughes, 2003, p. 3). I kept a research diary to document my research activities, thoughts, and feelings throughout the research process from design through data collection and analysis to writing and presenting the study (Bloor & Wood, 2006). Ongoing entries enabled me to be fully review my research motives. According to Blaxter, Hughes and Tight (2001), a research diary is an essential part of qualitative research. They suggest a researcher should reflect on four different aspects of doing research and their role within the construction of knowledge by document observational, methodical, theoretical notes, and analytic memos. Overall, the use of these strategies strengthened the validity of this qualitative case study.

Statement of Subjectivity

I am an African-American female who was raised in a working-class family and low-resourced rural county. I have taught in affluent and poor school districts in the United States and United Kingdom. My education journey as a student and professional has been immersed with learning new strategies in formal and informal learning settings to prepare myself for the demands of the global society. I have eight years of teaching experience in science and technology and nine years of experience managing science, technology, engineering, and mathematics programs for underrepresented minority students and working with teachers.

My role as a STEM program manager has allowed me to develop high-interest programs to engage students and work with teachers in developing learning experiences in teams using physics, technology, and instructional strategies differently then they may in their classroom. It has also provided me the opportunity to observe the educator's response to new approaches, unfamiliar content, and technology tools. My research interests are grounded in finding ways to prepare students for the future through using informal and formal learning environments to address the needs of teachers in a professional and supportive learning laboratory. I have reflected critically on my beliefs regarding this research in order to address ethical research guidelines in social science research. I had to acknowledge that I designed the Photonics Blended Learning Teacher Professional Development program and integrated the innovations into the hybrid model to introduce teachers to strategies that are effective in preparing all students for the global society. As one of the principal investigators of the project, I have interacted with the workshop participants on different levels. For example, some teachers worked in the photonics student program component, developed curriculum materials, volunteered in the program, or worked in the middle school science program as an instructor. These experiences, from an emic perspective, have provided me information about the program and teachers that has stimulated my interest to understand more about the intervention from the voice of the participant. Being able to balance my role as the researcher, participant and creator of the program has allowed me to more accurately and holistically describe the native experiences of the teachers using contextually-based, thick, and rich descriptions. Stake argues that a need exists to contextualize data through acknowledging the situated and cultural nature of instructional programs (1975, 2005). Throughout the process of conducting this study, I have honored the tenets of social research and worked towards a balanced emic and etic perspective in the study to manage my personal bias.

I am also a science educator who loves learning and finding creative ways to integrate technology and research-based techniques into the learning experiences of science students. The infusion of technology in our society has opened doors for schools and teachers to use technology as a tool in the classroom and a learning environment in transforming ways. With so many demands placed on teachers in the classroom, little time is given to fully understanding and utilizing new technologies, especially web-based strategies that may require more time to learn and flexibility to effectively impact student achievement in science. A small number of science educators are utilizing technology in ways that will extend learning from its traditional didactic approach. I believe that all teachers possess the knowledge, skills, and capacity to use technology effectively in their science classes and that a blended-learning model can be an effective way to immerse educators in a supportive professional learning environment to discover the benefits of technology in science instruction and provide ongoing professional support for teachers. This approach could lead to teachers developing a deeper understanding of how to use technology and support classroom implementation of resources to support science instruction. Science educators are essential in preparing students for the future, and we must provide innovative research-based models and relevant science content to contribute to their life-long learning pursuits. I opened myself as a researcher to understanding the experiences of all participants in this study, even those whose beliefs conflict with my own, to determine what aspects of the design worked well and what could be improved. Connecting with educators provided a platform for that exchange of knowledge.

Lastly, I paid close attention to my personal researcher bias and interests by documenting my personal impressions, assumptions, and beliefs in my research field notes to address issues of confirmability (Shenton, 2004). Additionally, the methods for data collection, interviewing, and coding were documented fully disclose my assumptions and methods used in the research study to strengthen the study's objectivity. Triangulation of data sources allowed for the corroboration of findings from qualitative results, saturation of data, and the emergence of categories to describe the science teachers' experience.

Summary

The purpose of this qualitative case study is to understand the learning experiences of teachers in PBLTPD and how these experiences translate to the implementation of photonics content, inquiry based strategies and web-based technology in their classrooms. Chapter Three explained the research approach for this study. In particular, this chapter described the qualitative research paradigm and the case study approach, and explained why they were chosen to answer the research questions guiding this study. This chapter also specified the data sources, notably pre-program survey data, interviews, and documents, and explained how these sources were be analyzed with a constant comparative method. Lastly, Chapter Three outlined methods taken to increase the reliability and validity of the study. Chapter Four provides an overview of the findings from the analysis of data sources.

CHAPTER FOUR: FINDINGS

This chapter begins with a description of the purpose of the study and research questions. Next, using information study participants provided through a demographic survey prior to the interview, I describe the teachers: their genders, working experience, and school districts. I complete this chapter by presenting the findings based on analysis of the archival documents, and interviews. The findings are organized according to the research questions guiding this study.

Study Purpose and Research Questions

The purpose of this study was to examine science teachers' learning experiences in PBLTPD, a blended-learning photonics teacher professional development program and to identify factors that contribute to participants' use of strategies introduced in PBLTPD. Rogers's (2003) diffusion of innovation theory was used to understand teachers' adoption decisions, their perception of the innovations' characteristics (relative advantage, compatibility, complexity, trialability, and observability), and their adoption or rejection of PBLTPD innovations. This study specifically focused on which of the innovations' characteristics play a key role in decreasing or increasing teachers' uncertainty regarding use or non-use of innovations introduced in the PBLTD professional development. The research questions were:

1. What are teachers' experiences in the Photonics Blended Learning Teacher Professional Development program?

2. How do teachers implement innovations from the Photonics Blended Learning Teacher Professional Development?
    a. How do participants implement photonics content?
    b. How do participants implement inquiry-based approaches?
    c. How do participants implement web-based technologies?
3. What facilitates or impedes science teachers' implementation of Photonics Blended Learning Teacher Professional Development innovations?

To learn more about factors that influence teachers' adoption of innovations in a hybrid science teacher professional development, I interviewed 15 science teachers and reviewed over 100 archival program documents. Document analyses and semi-structured interviews were conducted from mid-April 2013 upon receipt of IRB approval until there was data saturation, which occurred in mid-August 2013. A pilot interview was conducted with one workshop participant who taught elementary and middle school and was used to revise the interview protocol prior to interviewing study participants.

Fifty-seven science teachers were invited to participate in PBLTPD study through email. Two weeks later, I followed up with a phone call to arrange interviews with 15 teachers who had participated in PBLTPD. A confirmation email (Appendix I) was sent to confirm each interview time and outline the study's purpose, risks, benefits, and research requirements. Each study participant was instructed to read PBLTPD informed consent form, sign, and date the document electronically; complete the demographic survey prior to the scheduled interview; and call me 15 minutes prior to the interview time. When participants failed to call at the scheduled time, I called at the scheduled interview time and rescheduled when needed.

Participants were selected according to pre-established criteria: all participants were participants of PBLTPD, had completed an implementation plan, and represented one of three implementation levels: a) Level 1: Completed the face-to-face training, used strategies with students in their classroom, participated in the online follow-up component, b) Level 2: Completed the face-to-face training and online follow-up, but did not use strategies in their classroom; and c) Level 3: Completed the face-to-face training and used strategies, but did not participate in the online follow-up component of PBLTPD.

Interviews were conducted on the phone to eliminate potential technical problems associated with online interviews as well as to accommodate participants' schedules and their diverse geographical locations. Interviews lasted a minimum of 40 minutes and no more than 90 minutes, for an approximate total of 900 minutes of interview data. Research journal entries were recorded after each interview to document researchers' reflections. All interviews were transcribed by a hired transcriptionist and reviewed by me for validity of content prior to coding. Each interview was coded inductively line-by-line to identify emergent categories based on recurring words and ideas and deductively with a priori codes based on Rogers's (2003) attributes of innovations in *Atlas.ti* (Scientific Software Solutions, 2013).

Participants

A sample size of 15 teachers participated in PBLTPD study. Years of teaching experience of the sample size ranged from three to 24 years, with an average of 13 years of teacher experience. Race/ethnic backgrounds of the sample participants included Caucasian, African-American, African-American and Hispanic, and Asian. Grade levels and subject areas taught by the participants varied and included one elementary language arts teacher who taught science up to April 2013, six middle school science teachers, and eight high school science teachers. Several of the high school teachers taught more than one subject area. Sample participants represented rural and urban school districts from nine North Carolina counties in Tier 1, 2, & 3 economically distressed regions. These regions were located in Alamance, Cumberland, Davie, Durham, Winston Salem-Forsyth, Hoke, Orange, Pender, and Wake counties. Table 4.1 provides a brief profile of participants' cohort assignment and demographic details. To ensure confidentiality, teachers' names were pre-linked to a number identified by the researcher. The cohort value denotes when each teacher participated in PBLTPD program. For instance, cohort one entered the program in 2009, cohort two in 2010, and cohort three in 2011. Overall, each teacher participated in the program a minimum of two to a maximum of four years from the time of data collection.

Table 4.1

Participants' Demographics (N = 15)

Name	**Sex[1]**	**Race/Ethnicity**	**Teaching Experience (Years)**	**Grade Level 2**
Angela	F	African-American	7	HS
Timothy	M	Caucasian	15	MS/HS
Cathy	F	Caucasian	6	HS
Thomas	M	Caucasian	18	MS
Ann	F	Caucasian	24	MS/HS
Holly	F	African-American	9	MS
George	M	African-American	8	MS
Chris	M	African-American	10	MS
Lynn	F	Caucasian	18	HS
Jim	M	Caucasian	3	HS
Paul	M	Caucasian	26	MS
Regina	F	Asian	10	MS
Janet	F	African American-Hispanic	5	HS
Molly	F	Caucasian	14	MS
Susan	F	Caucasian	20	MS

[1] F=Female, M=Male; [2]MS=Middle school; HS = High school

Table 4.2

Sample Participants Cohort Assignment and Rural Economic Tier

Name	**Rural Economic Tier**[3]	**Subject Area**[4]	**Cohort**
Angela	2	B, A&P, & GSI	1
Timothy	3	C, PS, & APEB	1
Cathy	3	P	1
Thomas	2	GS	2
Ann	3	ELA	2
Holly	3	GS	2
George	3	GS	2
Chris	3	GS	2
Lynn	3	ES	2
Jim	1	PS, C, & P	3
Paul	3	B & C	3
Regina	2	Sixth Grade Science	3
Janet	2	P, C, & B	3
Molly	3	C, PS, & A	3
Susan	3	GS	3

[3] **3 = least economically distressed, 2 = moderately economically distressed; 1 = economically distressed**
[4] *****A&P=Anatomy and Physiology, *APEBio=Advanced Placement Environmental and Biology, C-Chemistry *EL = English Language Arts, GSI-Global Science Issues, *P=Physics, PS= Physical Science, *GS=General Science*

Participant Profiles

Angela is a high school biology teacher at an urban magnet school located in a Tier 2 economic distressed county. African-American and Latino students in grades sixth through twelve attend her school. With less than ten years of teaching experience, she actively seeks out learning experiences to enhance her teaching repertoire and knowledge of physical science because it is not offered as a course for students at her school. Hence, she selected the optics and photonics workshop having expressed the hope to influence how she taught biology, anatomy, and physiology through the addition of physics content, new pedagogy, and web-based technology tools. When asked by her district coordinator to transfer an end-of-course biology class to an online format, she was prepared to face the new request based on her participation in PBLTPD. She indicated that she didn't feel comfortable with the physics content in PBLTPD and that she has taken other courses to learn more about the physics content, problem-based learning method, and web-based technology tools.

Timothy is a high school environmental science teacher who teaches at an urban high school in a tier three economic distressed county. He has 15 years of teaching experience with academically challenged, average, and advanced students in alternative and public school settings. He has continually immersed himself in learning more about optics and photonics content, inquiry-based practices, and web-based technology skills through his engagement in a plethora of professional learning programs at NC State University, Duke University, and the University of North Carolina Chapel Hill. He expressed that he learned more after the professional development because he realized the application and intricate connections among content, pedagogy, and technology tools through teaching it in Photonics Leaders II informal learning setting, seeing its applications in schools, and learning these innovations in other learning settings. He shared that he is still processing how to best deliver inquiry-based strategies in his classroom to engage learners, but his level of comfort has increased as a result of his participation in PBLTPD.

Cathy is a high school physics teacher who teaches at a public charter school in a Tier 3 economically distressed county. She has six years of teaching experience at a small suburban school with a predominant white student population. She sought out the workshop to acquire resources, hands-on activities, and connections with professionals in the classroom to support her transition to the classroom as a new teacher. Her experiences in PBLTPD program and the student program equipped her to be a leader at her school using optics and photonics, inquiry-based, and web-based technology innovations.

Thomas is middle school science teacher with more than 15 years of teaching experience in a rural, relatively well-resourced school comprised of a student population of 95% White students. Approximately, 40% of students in this Tier 3 economically distressed county receive free and reduced lunch and have limited access to technology. He noted the greatest disparity and struggles among the students at the school is economically related.

Ann is an English language arts reading coach who works in a Tier 3 economically distressed county. With 24 years of teaching experience in science and English, she has taught science to grades sixth, seventh, eighth, and kindergarten both in the United States and Mexico. She participated in the workshop to acquire more science content knowledge to teach a sixth grade curriculum at her school, a new assignment to teach content for which she had no previous experience or training to teach.

Holly is a middle school science teacher who works in a Tier 3 economically distressed county. With nine years of teaching experience within an urban setting, she has taught sixth and eighth grade general science. She participated in the workshop to acquire more resources to teach light and optics concepts to sixth grade students.

George is a middle school general science teacher with a total of eight years of teaching experience in Tier 2 and 3 economically distressed counties in North Carolina. He has a background in biology and has taught high school physical science and general science to middle school students. He works in a one-to-one county where technology and inquiry-based instruction are cornerstones of the education system and district-wide support and resources are in place to facilitate their implementation into the classroom. He participated in PBLTPD to learn more physics content. Since his participation in PBLTPD, he has participated in 20 professional development programs on web-based technology and inquiry-based instruction. He is a leader in his county with employing web-based technology and inquiry-based approaches in his classroom in transformative ways.

Chris is a middle school science teacher who works in a Tier 3 economically distressed county. With ten years of experience teaching, he is employed at a magnet school where he has the freedom to integrate curriculum in his class to equip students for deeper learning experiences in science and mathematics. He participated in PBLTPD because it met a specific purpose in his classroom and would help him prepare students for physics learning experiences.

Lynn is a high school science teacher with eighteen years of teaching experience in a Tier 3 economically distressed county. She currently teaches environmental science and uses elements of optics and photonics into her course. She describes herself as a hands-on, tactile type of learner who did not feel comfortable with the online learning component of PBLTPD. 80% of the students receive free and reduced lunch.

Jim is a high school science teacher with three years of teaching experience in a Tier 1 economically distressed county. He has taught chemistry and was recently appointed to teach physics and physical science. He is currently working on his graduate degree in physics and is seeking ways to expand the number of rural students' interested in taking physics at the high school level. His county did not have resources or funding available to support his implementation of optics and photonics, but resources obtained from the workshop were found to be helpful in class. Jim foresees greater use of resources with his new course assignment and administrative support.

Paul is a veteran science teacher who teaches in a Tier 3 economically distressed county in North Carolina. He teaches biology and chemistry in an international baccalaureate (IB) course for students in grades six through ten. The urban magnet school accepts students from all over the county and within the school's local neighborhood. He delivers content differently to students with different academic levels and has participated in numerous professional developments, led science professional developments, and developed online courses in Moodle®.

Regina is a middle school science teacher with ten years of teaching experience in a Tier 3 economically distressed county in North Carolina. She works with low ability, average and advanced students and was seeking a content-focused professional development that would support her teaching and instructional needs to deliver sixth grade science content. Her rural school has limited resources and funding to support her science instructional needs.

Janet is a high school chemistry teacher who teaches in a Tier 2 economically distressed county. She is the only physics and chemistry teacher at a small charter school for 200 students. She has a new principal who supports students learning science in an engaging and effective manner, but she has not received any funding for resources.

Molly is a veteran teacher who has worked at a struggling middle school and currently works at a better-managed magnet high school in a Tier 3 economically distressed county. She is a tactile, hands-on learner and believes that students learn best by being engaged in hands-on learning experiences and by allowing them to make individual discoveries. She notes that teaches in both schools do not like to share resources. She participated in PBLTPD because she desired to learn something new and was excited to learn content related to the science of light.

Susan is a middle school science teacher with twenty years of teaching experience in a Tier 3 economically distressed county. She works at a coastal rural school with less than a third of the students on free and reduced lunch. She participated in PBLTPD because of her previous experience with The Science House's professional development programs and a desire to learn more about light for her sixth grade curriculum.

Participation Summary

When asked why they decided to participate in the study, teachers expressed different motivations. Both middle and high school teachers opted to participate because they wanted more content training in optics and photonics, they were seeking out an opportunity to learn something new, they desired to engage learners in learning about research and real world applications, and they wanted to acquire curriculum resources and materials for their classrooms to address the standard course of study requirement. Also, a few noted the stipend as an incentive to participate in PBLTPD.

Though several participants did indicate some difficulty with remembering everything they learned in PBLTPD, all were able to share their experiences, describe what they learned, and explain what they used in their respective schools and other settings. The key advantage of focusing on teachers at least two years after their participation was it allowed me to discern whether changes, if any, in teachers' use of strategies introduced in PBLTPD were sustained changes that persisted (i.e., long-tern) and applied to different situations—both of which are more indicative of real change in behavior than initial changes that may have been documented in an immediate follow-up.

Overview of PBLTPD

To understand implementation, it is important to first understand what teachers did in the Photonics Blended Learning Professional Development (PBLTPD) program because intended design and actual implementation can vary. Rather than describing what was the intention of PBLTPD creators, this section briefly highlights what participants actually did in PBLTPD.

Face-to-Face Component

PBLTPD had two formats, face-to-face and online. The program agenda each year was slightly modified to incorporate curriculum modules on solar cell characterization, light emitting diodes, and fiber optics. On the first day, teachers were introduced to key photonics/optics concepts: color, light, electromagnetic spectrum, reflection, refraction, interference, holography, polarization, spectroscopy, solar cell characterization, light emitting diodes, circuitry, fiber optics, and energy efficiency. The inquiry and content investigations immersed teachers in inquiry-based activities whereby teachers solved the problems in groups and discussed the content in small and whole group settings with the facilitator, an engineer with training in optics and photonics content. This 8-hour day consisted of an introduction to basic light concepts and more advanced content.

During the second day, teachers toured research laboratories at North Carolina State University. Lab tours were somewhat different each year. In cohort one, they toured the Light Detection and Range Sensing (LIDAR) facility, the Analytical Instrumentation Facility, the Opto-Electronics & Lightwave Engineering Group (OLEG) laboratory, and Universal Laboratory, Incorporated. Cohort two toured the Light Detection and Range Sensing (LIDAR) facility, the Analytical Instrumentation Facility, the Laser Laboratory, and the Opto-Electronics & Lightwave Engineering Group (OLEG) laboratory. Cohort three toured the Light Detection and Range Sensing (LIDAR) facility, the Analytical Instrumentation Facility (AIF), the Laser Laboratory, the Opto-Electronics & Lightwave Engineering Group (OLEG) Laboratory, and the Nanofabrication Facility. Physicists, engineers, graduate students, technicians, and lab managers from the Department of Physics and the College of Engineering at North Carolina State University led participants through laboratory tours and demonstrations. These physics and engineering tours entailed teachers using robust equipment; participating in demonstrations related to lasers, nanotechnology, and optics; performing experiments related to research on liquid crystal displays; and learning how to teach these concepts to students in a simplistic and relevant way. They also learned about STEM careers and how to encourage students to prepare for future careers in these areas. Each day participants completed a reflection. Their reflections indicated that participants learned some new and useful content and became aware of the university environment including the robust technical equipment that supports groundbreaking research projects at the university and industry levels. Janet, Regina, and Susan noted the laboratory tours were useful and informative for many reasons. For instance, Janet mentioned:

> I learned how the different instruments work and why they are used. I also learned the purpose of a 'clean lab'. The information I gathered, I plan to share with my students. At the beginning of the semester, I assign my students a project to look up ten physics and chemistry related careers. I always get the same jobs. This experience has allowed me to see what an array of positions are out there is just photonics/optics alone. It was very interesting. I was glad to actually see the

> instruments that I often see in the textbook. I also learned new techniques that I will use in my classroom. For example, the different rocks and how we can determine the elements within it by just shining UV light. I know my students will enjoy that.

Regina acknowledged that Dr. Philbrick from LIDAR laboratory showed her what activities she could do with middle school students. Susan shared that the lab tours were interesting and a highlight for her was seeing an electron microscope. She explained:

> I have wanted to see an electron microscope all my life and never thought I would be able to, so that was a highlight. Going into the clean room and understanding how they work and how the semi-conductors were made was super interesting. Seeing the different jobs and what kind of information can be gained from the research was also interesting.

On the third day, teachers attended a session on how to harness technology to help learners understand science and develop requisite 21st century skills. These sections were led by three individuals: a research professor who authored books on *Physlets*, scientific visualizations; a chemistry and physics high school teacher who demonstrated low-cost, inquiry-based, content activities related to the nature and properties of light reflection, refraction, interference, illusions, and color; and an Elluminate Coordinator who led a technology session on web-based technology tools, Elluminate, Wikis, and Moodle, to introduce participants to the interfaces and features that teachers could use as a learning space to engage students. Teachers learned how to use *Physlets* simulations to support students' conceptual development of light and physic-based content. For cohorts two and three, simulations were introduced in conjunction with specific content taught during the inquiry and content day to provide specific examples related to content learned in the workshop. On the final day, teachers created implementation plans to outline what they proposed to implement in their classroom or school over the next three to six months.

Online Component

Prior to the workshop, the technology coordinator sent each participant an orientation manual that provided basic login procedures and connection tests for all participants to perform remotely prior to the workshop to ensure remote access to the technology. Each evening during the workshop, the technology coordinator provided an additional Elluminate orientation for participants. Teachers were introduced to how to sign in to the interface; how to setup the audio and voice inputs; and how to use the chat feature, emoticons, breakout room features, download documents, hand feature, poll feature, drawing, text, and whiteboard features to interact with teacher peers and facilitators in Elluminate. Archival program documents revealed that the Moodle incorporated the second year to replace Wetpaint and all programmatic documents (agendas, directions, reflections, assessments, web-based resources and links to career information related to optics and photonics) were housed in Moodle ®, an online learning management system. Only a few of participants reported using web-based technology tools prior to PBLPTD. Teachers were directed to use the space to upload their reflections, questions, lesson plans, and participate in discussion with their peers. Teacher input was minimal among participants in the space.   Generally, they used the space to upload required documents and acquire information but very little for discussion with their peers. More discourse occurred synchronously in the face-to-face setting and in live online meetings in Elluminate. Participants did experience some technical problems with accessing Elluminate and navigating Moodle.

The online workshop component also included content that addressed web-based pedagogical strategies, problem-based learning, and the assessment of photonics problem-based learning (PBL) multimedia curriculum resources created by the New England Board of Higher Education National Science Foundation Advanced Technical Education Photon Project. Teachers provided an update of their implementation progress, and select teachers presented their initial implementation findings from their school during the session. The remainder of the session was committed to teachers going through the PBL module on lasers as a team to understand what student learners would experience in the classroom. Attendance to follow-up sessions was relatively lower in attendance (40% to 50%) than in the face-to-face meetings (100%), largely due to scheduling conflicts and teachers' extracurricular duties. Absent participants were sent a link to view the follow-up session.

Presentation of Study Findings

In the next sections, I present the research findings. The results are organized according to the three major research questions. There is some overlap in findings largely a result of the nature of the investigation; notably the research questions are interrelated. Open and axial coding of the primary and secondary data sources were used to identify recurring words and ideas, core categories, and subcategories. Rogers's (2003) attributes of innovations theory were used to explain factors that contribute to an individual teachers' decision to use the innovations presented in PBLTPD.

Research Question 1: What are teachers' experiences in the Photonics Blended Learning Teacher Professional Development program?

Table 4.3 outlines the two overarching categories related to teachers' experiences with PBLTPD: a) learning—what teachers perceived they learned in the program and b) challenges—what difficulties experienced in the workshop. Six sub-categories for learning and seven sub-categories for challenges are also outlined in Table 4.3.

Table 4.3
Teachers' Learning Experiences and Challenges in PBLTPD

Categories	**Subcategories**
Learning	• Optics and Photonics Content • Materials/Activities • Teaching Strategies • Collaboration • Optics and Photonics Applications and Careers • Broader Awareness of web-based technology
Challenges Face-to-Face	• Understanding all the information • Translating learned information for understanding • Learning in a multiple disciplinary science backgrounds
Online	• Technical problems • Moodle and Elluminate application/features • Comprehension of web-based technologies • Integration of web-based technologies

Overall, the participants perceived the workshop to be a comprehensive, hands-on, collaborative professional development that included a tremendous amount of information, resources, and support to guide their learning experience. For example, Chris, a middle school science teacher who is employed at an urban charter school described PBLTPD:

> It was extremely comprehensive. It was surprising for me that it spanned two days and it was on a Saturday, but it was really hands-on. And one of the things that I appreciated about this particular workshop is that it gave you time to actually practice the theory that we talked about. So it was kind of like lecture and lab at the same time, and so it gave us some time to really play with some of the information that we learned about.

George valued the hands-on activities of the workshop that allowed him to experience the activity in the same way that students would in his classroom remarking:

> One of the best part[s] about the photonics program is we did all these hands-on experiments which, teachers don't get that experience. Sometimes it's kind of a sink-or-swim nature. You can go try some things and see if it works or throw some things together and see if it sticks, but you really don't get an opportunity prior to the classroom to work things in with a group of students. So it was great to have a program where you actually did the activities with the students; it was like you were learning together. And again, we don't have that much time. So the photonics program offers practical applications of a lot of the concepts and activities that we were able to get and to work with the students.

Similarly, Paul indicated that he appreciated the opportunity to work through the very activities that he could use with students, sharing:

> [You] had much smaller groups, you could do things, you worked through the activities to make sure you understood them yourself, and you had something you could take back at least to use as a demonstration or model for your students if you couldn't get more of it so that every student could put their hands on it.

As Molly discussed, PBLTPD not only provided hands-on activities, but also the program provided participating teachers the opportunity to make meaning of the experience by collaborating with colleagues:

> I liked having hands-on; I liked seeing how other people do things; I liked being able to talk to other people from other areas, you know, of our district. I mean, most of the time when you do PD, it's, you know, you see the same people.

In addition to valuing the hands-on nature of the program, many teachers shared that they believed that the content was useful because it was relevant to what they taught, and they believed it would be interesting to the students. Cathy, a high school physics teacher, for example, explained how relevant and applicable the workshop was for teaching optics and photonics to high school students in comparison to other physics-based professional developments she participated in the past in noting in her reflection:

> Again, I thought going into it that it would be a good choice because it was one of the hands-on type of workshop; other workshops that I go to, if they are about Physics topics, they're either topics that the students don't need to know, or are going to be

> over their heads, or are not for their level, or are just people giving presentations or lectures about lessons. And this particular one that was with The Science House was just completely relevant, it was on the level that I needed, and it was hands-on, which is the key component.

Lastly, participants shared that it was not just the content they appreciated; they valued being treated as professionals. Susan's comments reflect this perception of being valued:

> [Our workshop] is a complete 180-degree difference from how you all run a workshop. You fill the time, you have activities; those activities apply to what we're doing in the classroom. You know, there was always something there. People were driving in two hours to get there to a workshop. Having a bottle of water or a bottle of juice there, it makes you feel welcome. It makes you feel like somebody cared at least, and that is not what happened in my [rural] county this year.

In the next section, I present categories that describe what the teachers learned from PBLTPD.

Optics and Photonics Content Knowledge

The middle and high school teachers attended PBLTPD workshop because they were seeking a more content-focused professional development that would provide them the opportunity to learn new information. They described the workshop as well-organized, fun, intensive, and informative to them as science educators. George, a middle school teacher with a biological science background, participated in the workshop to increase his knowledge of physical science. He wanted to acquire more physical science content knowledge because he believed that teachers are more confident when they have an understanding of the content they are assigned to teach students. He conveyed this view when he shared:

> I was excited. There was a pre-test and a post-test, and I mean I knew in looking at the questions pre- and post-[assessment] that I had learned a lot of content as far as physical science—that's not my specialty. I was a biology major in college, so I was stronger in chemistry and the biological sciences than I was in the physical sciences, so what I gained from it was content knowledge, number one. One of the things as a teacher, the more content knowledge you have, the stronger and more confident you feel as a teacher, so that was the main thing.

Teachers expressed that they learned optics and photonics content that they did not know prior to participating in PBLTPD. Lynn, a high school teacher who taught physical science and a "Future Decision in Science" course, shared what she learned from the professional development:

> Well, there are a couple of different areas. One thing I learned was about the nature of photonics, how it acts as a wave and a particle, and just, I guess, the content about photonics was one thing that was very useful to me, which I alluded to in my first question. I knew it was a wave particle—I knew that, but then the many ways that is being studied and the many uses it has. So that was the first thing I learned the content.

Molly, a high school teacher with fourteen years of experience, decided to participate in the workshop because it covered the science of light, which she could add to her teaching repertoire. She described how she learned about fiber optics. In contrast, Susan, a veteran sixth grade teacher, wanted to learn more about light which is part of the sixth grade [North Carolina] Essential Science Standards, but learned not only about light but also other concepts:

> There were just so many things that I have gotten out of that workshop and put into practice in my classroom. The list really is endless, not only from what you all taught, but just talking to other teachers that were there and things that they did in their classroom. I mean I could hit some high spots like angle of reflection, you know, and things associated with that. The LCD (liquid crystal display) circuits—I use those now with the kids. Nanotechnology was something that I really couldn't have talked to my kids about at all, and now I feel like I can at least explain it to them, especially the poster that you all had there. We talk about jobs and careers for kids that, you know, they're not going to think about that I didn't know about either. Wow. Understanding how the human body perceives light and colors and other structures, all of that.

All in all, the participants' data revealed that PBLTPD provided them opportunities to learn about the basics of light, its tendencies and applications that could be used in their classrooms.

Curriculum Materials and Activities

Though the teachers in the study represented different school districts and experience with teaching optics and photonics content, the teachers discovered new curriculum materials and activities to support their use of the content in their respective classes and schools. Lynn is a high school environmental science teacher from an urban county. She shared that the materials and activities would enhance her students' understanding, especially the "Mirror, Mirror on the Wall" angle of reflection activity. Several of the teachers shared that the curriculum activities and resources introduced in PBLTPD were new, interesting, relevant, and provided practical applications for the classroom. For example, George described how the materials and activities from PBLTPD complemented his new understanding of the concepts:

> A lot of PDs—professional developments—we have at the school are one day or one hour, and that's not enough. That's not enough to really get anything out of it, and the application part of it is even tougher because you don't have time to get deep into something you just learned and you're really excited about trying it. So the photonics program offered practical applications of a lot of the concepts and activities that we were able to get and to work with the students.

Janet reported how the photonics materials and resources she acquired in the program two years ago now aligns with the new Essential Science Standards in North Carolina; she also stated that they were easy-to-implement and exciting. Janet shared:

> They [curriculum materials and activities] were new; they were exciting. Some of them, it didn't take a lot of materials. I was given a fiber optic box that has the fibers in it, and I was able to use those things that were given to me. I have a number of things that were given to me from different facilitators, so I was able to use those things in a demo. If I didn't have enough for students, I had enough to show to them and do a teacher demo, so I used those things that were given to me during that workshop. Our new essential standards now, a lot more of those things that we were doing in this workshop that I did two years ago are in the new official standards such as the bubbles interferences & the Tyndall effect. So I was able to use the labs that I did two years ago on a unit now with objectives that have changed.

Additionally, Regina claimed that the use of curriculum materials and resources related to light perception, solar cells, lenses, image formation, and problem-based learning modules with sixth graders were much needed enhancements to her unit on light traditionally taught didactically:

> I have used different activities like a bag full of objects [used to explore] how light is perceived. Some of them are easy and some of them are really hard. And, I have also used solar panels [with] different kinds of connections. So those are specifically different things that I have used and I'm still using the hands-on activities that were geared toward how light is perceived; problem-based learning module; and the hardware we were using—the lenses to see how an image is perceived.

Lastly, Paul noted how the activities and materials he acquired from the program were such great activities that he used what he could not utilize in his classroom with an after school program because they were relevant and would facilitate students' independent exploration and understanding of science:

> I've used it in my after-school Science Club to work with the interested students there to demonstrate a lot of information or things about light, electricity, and ideas for electronics and to give kids some hints for science fair to give their some fair project.

This next section discusses teaching methods that teachers learned by participating in PBLTPD.

Teaching Method

Jim, a teacher from a rural under-resourced high school, discussed how his PBLTPD experience contributed to expanding his awareness of different instructional strategies for teaching waves and optics, which he believes are rather complicated concepts to teach students. He shared:

> It had been so long since I had studied anything with physics with waves and stuff, and learning some pretty—not complicated, but not simple—ideas as far as trying to get waves across to kids and dealing with optics and how to apply different ways of teaching and reflection and things like that go hand-in-hand with the actual course curriculum.

Paul also learned new approaches to demonstrate light and other concepts to school students, saying, "Well I learned some ways to demonstrate some of the characteristics of light and things that you can do with light with my kids although it doesn't work as well in our new standard course of study." Regina shared how her experience in PBLTPD provided her the confidence to use more inquiry-based teaching methods with students in her class rather than traditional lecture style approaches for her light unit. She shared the following:

> I came to know different things that I could do with more hands-on learning, but earlier when I used to teach this curriculum, it was more like lecture and it was more like showing visuals, but I did not do many hands-on activities that could go with the curriculum, so attending this workshop helped me figure out.

Teacher Collaboration/Networking

As part PBLTPD program experience, participants were placed in an active learning environment to carry out the hands-on activities, make observations and predictions, and share their findings within their group. The approach helped teachers learn to work together to understand the science phenomenon in each activity. Altogether, PBLTPD supported teachers learning through collaboration and teachers learning how to collaborate. Holly, a middle school science teacher, indicated that the most she obtained from her experiences occurred through collaboration with fellow participants and activities that were replicable. Janet, a high school physics and chemistry teacher from a rural county, shared that she too learned from her peers:

> I also learned just networking with other teachers, different techniques that other teachers use during their classroom instruction that I incorporated in mine. I learned

> new teaching methods; just a greater understanding of science and in that particular subject about photonics and all that it incorporated.

Whereas these comments highlight how teachers learned about the content and teaching strategies by collaborating, others' comments revealed the workshop actually taught them how to collaborate. For example, Cathy expressed that she had not expected to learn about collaboration by participating, but it has helped during her initial years of teaching at a charter school in an urban district:

> I really learned a lot about, honestly, collaboration, which is not what I had expected to learn. The optics component—I guess I was maybe a second year teacher at that time, so I didn't have a lot of resources anyway, so the activities that we did helped me tremendously in my day-to-day lesson planning and meeting other teachers who taught the same types of things I did and being able to have communication with them since we were able to have everyone else's emails that participated in the workshop.

George's comments also convey how PBLTPD helped teachers in the program realize how learning with others promotes learning:

> The other thing that I've learned is how important it is to work collaboratively. I had to work with other teachers engaging on the side of that, but more importantly, I had to engage with other teacher and the students together. That's how you learn. You work as a team and the learning process is even stronger. So the collaborative part of it was essential. The slowing down and developing those relationships were essential,

> and you think you learn the content, you've got all this stuff, you have got all these resources, that were secondary.

Optics and Photonics Applications, Research, and Careers

The university and industry laboratory tours exposed the teachers to research, its future, real-world applications and STEM career information. As Ann explained, "I think one of the most valuable things I learned is where the kids are headed." Ann also explained that the tours and interactions with physicists and engineers provided her a vision for the future of science and helped her better understand what students needed to know. Janet was especially appreciative of the opportunity to see real research because she had not had access to actual research laboratories in other professional development programs in her district. Thomas also valued the lab tours. He shared:

> I really liked the labs course that we did and the different equipment that was available there at State for them to look at . . . Like the laser imaging and vibrational spectroscopy lab tour was really interesting. I also had a lot of fun creating the liquid crystal display pixel. That was pretty cool. But, the lab tour component was one of the most interesting experiences I had at the workshop.

Janet made remarks about the advantage of participating in a teacher professional development where she learned about real research, toured the actual laboratories, and shared her assessment:

> Well, in comparison, my school district, when we go to our professional development, we don't have a university—well, we have a university, but our

> university doesn't have all the different—[equipment & instrumentation]. They don't have the textile labs or the type of labs that NC State like the clean lab. They didn't have it on a broad scale. The schools there, in my local area, are very limited. So attending this workshop, I was very excited to actually go onto NC State campus and actually go into those different laboratories that are in the industry, and so in comparison, I didn't get that experience in my local schools' professional development.

Broader Awareness of Technology and Web-based Tools

Although, a few teachers indicated that they had taken some webinars that used different web-based environments, and several indicated their use of technology was to share simulations with students and carry out teaching duties. The study participants had not participated in a hybrid science teacher professional development prior to their experience in PBLTPD. Fourteen of the fifteen teachers indicated that they had never used Moodle® or Elluminate®. The introduction to the web-based environments exposed the teachers to emerging web-based forms of technology that could be used in their schools. For example, Susan, a veteran middle school science teacher who views technology integration into her classroom as a weaker skill set, indicated, "You know, I can't say I'm efficient, but it broadened my experience with technology and, you know, having to use a computer and that whole getting together on the computer and having a meeting—that was totally new for me."

Timothy, a high school physics teacher with no prior experience with Moodle® or Elluminate®, shared how his introduction to these technologies through PBLTPD broadened his knowledge about what web-based technology environments were available:

> But without the photonics, that showed me what was available. I had no clue there was that much available with [web-based technology]. The first time I had seen anything on virtual remote was—we did a NASA field trip up to Langley. And this was like 10 years ago, and they were saying, "We can have virtual meetings with you guys. You've just got to go to a National Guard Armory." Five years later, we're doing it on Elluminate. And I'm just sort of just amazed how quickly the technology is. . . And now after the Elluminate, they're doing it routinely in the classroom. This has just amazed me.

These findings indicate that teachers in the program learned optics and photonics content and acquired resources that they could use in their classrooms to communicate fairly complicated information in accessible and engaging ways. Also, teachers acquired new or expanded old teaching strategies to demonstrate content to students and further enhanced their ability to collaborate with others in an environment with secondary and middle school teachers and college professionals. Lastly, they increased their awareness of web-based technology tools that may be used in their classrooms.

Challenges in Blended Learning Teacher Professional Development

Some participants faced challenges in both the face-to-face and online settings. Generally, their challenges fell into two broad categories: 1) technology and 2) content, collaboration, and application connections. George, a middle school science teacher, reflected on his use of blended learning environments:

> I still am having challenges. Blended learning is kind of a buzzword, but finding your balance was good for you. That's something I still wrestle with: How much is too much? And a lot of times, blended learning is based on teacher-centric activities, which it shouldn't be. It should be based on student-centric activities. The blended learning we think of as how much technology, how much classwork, how much collaboration—the teacher is organizing when the blended learning is how much of that is the student learning and how much are they using because the blended learning is for them. You should have blended learning based on what the student needs rather than the teacher and to disseminate. And again, finding that balance is very difficult because we've been taught for 50 years all students have to be at the same level, at the same curriculum, at the same content, and now with technology, that's not always the case anymore. We have the opportunity to let kids learn at their own level, at their own speed, and that is very difficult number one to let go, and number two to organize. And so, that's the challenge I think that I and a lot of teachers have is exactly finding a balance for me as a teacher but more importantly, for the students.

George's reflection provides insight into the pedagogical decisions and questions teachers may have regarding how blended learning can benefit their classroom instruction and most importantly, their students. Another middle school teacher, Regina, communicated the need for more participation and discourse from all participants in the hybrid professional development for it to be a meaningful experience for the participants. Her comments reflect the challenges of the hybrid environment:

> I think sometimes, like, logging in online and doing face-to-face can be a problem because it depends on the availability of the person, and when all people are not giving their feedback, I don't think it's very meaningful at that point. So if we can have more people giving feedback or talking online, that would be much better. So I didn't see that a lot with this workshop.

Study participants indicated that they faced several challenges in the face-to-face setting: 1) (connecting to all the information and content, 2) (connecting what was taught to information taught into classroom instruction), and 3) (connecting with their peers in PBLTPD). George noted the sheer amount and complexity of the information was a challenge for him:

> Probably digesting all the information, so there was time to actually do work on some of the theory that we talked about, but it was a lot of information, so some of the stuff, when I actually went back through the notebook, for me, kind of, like, was an afterthought. So it's kind of like I focused on this and that, but man, you know, going back over the information, "Well, I should have focused a little bit more on, like, the circuitry."

Paul noted that in every learning environment, whether face-to-face or online, information shared in PBLTPD must be translated by teachers for use in the classroom with their student. This was a challenge for him that he eventually overcame, as he explained:

> Like anything else, when you're doing something that's a little bit new, just like I tell my kids my job as a teacher is to translate science into America—things they understand, you have to learn the language that you're being instructed with and translate into the way you understand it.

Lastly, participants were placed in a learning environment that for some was unfamiliar and uncomfortable, specifically collaborating with their peers from different backgrounds. For instance, Susan found working with secondary science teachers intimidating, stating:

> I felt a little intimidated when I walked in there because there were so many high school teachers that have so much more background in Science and what they teach than I did. It worked out; I was able to adjust it for [myself as a middle school teacher], but I was like, "Oooh! These people really know what they're doing!" {Laughter} But it worked out.

Online

Participants in the workshop experienced technical difficulties learning about Moodle® and Elluminate®. Technology issues ranged from outdated technology equipment, inability to get online, issues logging into Moodle® and/or Elluminate®, activating the voice feature in the environment, and experiencing dissonance with understanding the role of technology in their classroom. Teachers discovered that online learning could present different challenges in different geographical locations.

Research Question 2: **How do teachers implement innovations from the Photonics Blended Learning Teacher Professional Development?**

Table 4.4 outlines how teachers implemented the three innovations presented in PBLTPD: content, inquiry-based strategies, & web-based tools.

Table 4.4

Teachers' Implementation of PBLTPD Innovations

Category	**Subcategory**
Content	• Student learning in classroom • Teacher learning in professional learning communities and school districts • Extracurricular learning programs
Inquiry-Based Learning	• Confidence builder • Differentiation for different learning levels • Exposure led to further investigation and practice
Web-based Technology	• Web strategies for student and parent engagement and student assessment • STEM Enrichment Program • Wikis/Simulations

The second research question focused on how teachers implemented what they learned from the program into their classroom and other settings. Teachers did use the content and resources in their classrooms, extracurricular settings, professional learning communities, within their district and in other areas. Overall, the participants incorporated photonics content and inquiry strategies more than web-based technology.

Content Implementation

The extent to which teachers implemented PBLTPD content varied, ranging from two teachers who did not implement any of the content presented to a few teachers who implemented the content in different settings—elective courses, after school programs, and professional learning communities.

Classroom

Teachers who were able to align the content with their current teaching assignments used the content to teach classroom lessons. Those who did not see a good fit between PBLTPD and the curriculum for their assigned courses increased their students' awareness of optics and photonics connections through extracurricular activities. For example, Susan, a middle school science teacher, indicated that she used the resources to teach sixth grade students about light and she really enjoyed using the activities to demonstrate light construction, enthusiastically sharing:

> Well, all the activities—literally all of the activities except for the project-based learning. I never got that instituted, but literally every activity that you did, I did in the classroom with my kids. I just kind of put it out there and ran with it; I tried to

> translate it to the students. The thing too is that I feel like I got so much out of that workshop that when we finished that workshop, I spent a good month on light. This year I didn't have that luxury, but I still spent about three weeks on light, just to do all the activities, and the kids loved it.

Although the photonics and optics content activities provided in the workshop were useful in assisting her with understanding the content, Susan had to slightly modify the content for middle school students to learn the information. She described what she did in her classroom and how she shared the content with other teachers in her school:

> Okay, well the one was the LED lab. All the background in there was good for me, but it was too high-end for kids, and so what I did was modified that down, and how I start that is we start with a regular, like what they would normally have in building an electrical circuit. Some of kids have done that and some of them have no clue. And so we use a battery, two wires, and a light bulb, and they have to construct a circuit, so then we move after that to using the bread board and the jumper wires and so we're able to talk about polarity and flow; we talk about polarized light; we do, I think when we were there we made that little polarized thing and I ordered some, they're like, little slides. They're something I used my grant money to get and they talk about polarized sunglasses. We did the activity, "Mirror, Mirror, on the Wall" where the kids start to understand the angle of reflection and we draw the angles. We use a flashlight and mirror and they then draw the angle and figure out the angle. And the color one was dependent on light; we do that one and we dissected a cow's

> eye. I kind of started that in my school, and it kind of caught on, and so all four of the science teachers did it this year for the first time.

Some teachers modified the activities because of a lack of resources to support their full-scale implementation. Molly acknowledges:

> I still have the kit, the little box that came, and I use that in my physical science [class], and I've used it since I took the workshop. I have the lessons that I've integrated into my own—kind of adapted more into my own since I don't have all the resources that I had there. I've added some things to my own school, but mostly just adding the lessons on light, the ones on electricity, the circuits, all that kind of hands-on stuff was great.

Some teachers also shared how they incorporated the content into across grade levels and content areas. Ann, who recently stopped teaching science, explained how the photonics and optics content was applicable to both middle and primary school students:

> I did that [photonics shadows and dark room unit] and I should say that I did that in my sixth grade classroom, in my eighth grade classroom, and again in my kinder-classroom. I've been in Mexico the last two years teaching in a kinder-classroom, and we did an entire project on photonics, shadow play, a dark room, and using an overhead projector to use transparent and opaque shapes to do, and all of that language I used even in my kinder-classroom.

Lynn, a high school environmental science teacher noted that a new teaching assignment redirected her use of PBLTPD materials and challenged her to think differently about light and photonics applications in a different subject area:

> Since I did the workshop, my teaching assignment has changed, and I'm not teaching physical science, chemistry, future decisions in science; I haven't since the workshop and so I haven't used that information as much. I am a more informed person, and I have used the electromagnetic spectrum [content in] my environmental science class, so [workshop has] informed my knowledge and [photonics] connections in the curriculum [and classroom] I'm teaching.

Teachers also went beyond their classrooms to use the optics and photonics content in professional learning communities (PLC) and extracurricular learning programs (i.e., afterschool, electives, and pre-college programs). Three middle school teachers indicated sharing this content with teachers at their school in their science PLC and school district meetings. Furthermore, in some cases, the optics and photonics content was diffused beyond the teacher's individual classroom of students to other middle and high school students in rural and urban areas. For instance, the statement below shows how Susan disseminated PBLTPD content:

> Okay, well, as I said, at the beginning of this year when we were having these workshops that we had to attend, the 6th grade teachers decided that we really weren't getting any Science content, we weren't getting any Science techniques from the people that were presenting the workshops; we were pretty much left to our own

> devices, and so what we decided that we would do is bring. . . As I said, everybody chose a topic that they felt strong in and nobody, of course, wanted the Physics because nobody felt strong in it, and I had just had the workshop. I said, “Listen, I will bring my notebook that you all provided for us and activities that I’ve done in the class with the kids and just show you what I’m doing.” And I know that people have picked up and are doing some of the same things; you only have a little bit of time to share. We were doing this in one day, and there were 6 or 8 of us there, so we each only had about an hour to show everything. So it wasn’t like it was in-depth, but I did take stuff, and they did do hands-on, and then at school what I’ve done with these other four teachers is be able to share all the activities and show them. So it’s definitely grown from just me attending the workshop at the Science House.

Regina, a veteran science teacher on her PLC team in a rural district with limited materials and activities to teach the sixth grade curriculum on light, worked to integrate what she learned and acquired from PBLTPD program into the PLC team to help younger teachers teach the curriculum on light:

> Yeah, we work as a group, so whatever I have, I will share with my colleagues, and whatever they have, they share with me. But unfortunately, my colleagues are first and second-year teachers, so they don’t have a lot of stuff to share. But whatever I have, I am more than happy to share with them. So I have shared with them. We discuss it; I show them some materials I have and the resources I have and then because we cannot teach at the same time since we don’t have so many things or so

> many materials, so I would do it on one day, and the next person would do it on the second day or third day depending on when I would finish or they would finish.

PBLTPD program provided Susan with content and activities that were useful in her classroom, for teachers at her local school, and within her rural school district.

Teachers found the optics and photonics content from their professional development useful and relevant and decided to use it in other settings to engage students in learning the content. Four teachers used PBLTPD activities in extracurricular learning programs for a variety of reasons, including not being able to incorporate all the content into the classroom, wanting to develop students' scientific and engineering skills, and informing students and their parents about light and it various applications. Each excerpt below reveals how teachers from middle and high schools went beyond the classroom to communicate optics and photonics to students and educators in afterschool programs, electives, and a school outside of their district (in Mexico), Ann shared:

> I have [used it] with three different grade levels and I was very excited to be able to pull it down into kinder. My students, I was in a project-based school, and my students were interested in light in my overhead projector when I did a math lesson, and because of that, that reminded me of that opportunity to have a darkroom, and so I built one underneath my loft. I hung a black curtain under my loft and my overhead projector and gave them stuff to play with. Then, we borrowed some laser lights from the physics teacher, the high school physics teacher that was in the same building, and we borrowed flashlights and we did all kinds of shadows, making

> shadows outside and inside, and measuring our shadows change during the day because of my experience four years ago, I was able to use it in three different grade levels.

Paul, a middle school science teacher, decided to create a science club to expose students to the optics and photonics content learned from the program. As he describes below, he used the content to expand students' interest in science and support independent research projects and basic exploration:

> Well, I learned some ways to demonstrate some of the characteristics of light and things that you can do with light with my kids although it doesn't work as well in our new standard course of study. But I use it more with [the] Science Club, but it's good to work through with the kids to show them something that don't really get in the regular science class**.** I've used it in my after-school Science Club to work with the interested students there to demonstrate a lot of information or things about light and electricity and electronics and to give kids some hints for science fair projects, to give them some ideas for science fair projects.

Whereas Paul used photonics content for learning experiences outside of the traditional school day, Chris incorporated the content into the curriculum, but outside of traditional course topics. He created an elective course to expose students to physics and physical science to prepare them for future exposure to the content and to build their interest in STEM topics. Chris said:

> Oh, I used it [optics and photonics content] in an elective, so when I say an elective, in my school, they give us a period to teach anything of our choosing, and so what I did was I taught an elective that had three parts: a forensics part; a dissection part; and then the third part was the photonics area. So basically I used that information that was in that booklet and the other materials that I had to actually teach about light, the spectrum, and everything else.

George shared the content across a wide range of settings, including his classroom, communities in schools, and an after school program. As noted below in more detail, he introduced the content to learners in different settings to translate information and knowledge to middle school students:

> In many ways, I've used it in my classroom. But I have a, I run an after-school program—communities in schools here in my county. And in many ways, I've used more of photonics content that I've had in after-school because one of the things we do in the after-school is the first hour is. . . I'm sorry, the second hour of after-school is actually a problem-based learning environment, and many of the things that I've learned—the writing. One of the things we learned about light, I used in the afterschool program. It's not a grade; it peaks interest in science in the kids. The kids in the program I run are more at-risk youth and most of them have, are a little more challenged with academics. So the unit on inquiry-based materials, hands-on materials stuff, I acquired from photonics and the processes from photonics. I've used a bit more in the after-school program given the amount of time because we use

> it for half the classroom. We probably won't have the opportunity in the classroom. But I've used a lot of content in the afterschool program.

On the whole, the findings revealed that teachers in the program found several ways to use the optics and photonics content and inquiry activities with students in elementary, middle, and high school in different settings. They used different formats to convey the content from the traditional classroom approach to a more exploratory approach. The next section describes in more detail how teachers delivered the content using inquiry-based and problem-based learning (PBL) approaches with students in their classroom.

Inquiry-Based and Problem-Based Learning (PBL) Implementation

Although some teachers mentioned that they felt confident using inquiry-based approaches in their classroom before entering into the program, several teachers indicated that being immersed in an inquiry learning environment with their peers increased their confidence and interest in using more inquiry-based or problem-based learning approaches in their classroom. In particular, PBLTPD helped the teachers learn how to carry out optics and photonics labs. Regina, for example, said that before the workshop she taught optics and photonics primarily by lecture, but after participating in PBLTPD, which allowed her to interact with other professionals that used the activities in their respective classrooms, she incorporated inquiry-based instructional strategies in her classroom. She shared:

> I came to know different things that I could do within more hands-on learning, but earlier when I used to teach this curriculum, it was more like lecture and it was more like showing visuals, but I did not do many hands-on activities that could go with the

> curriculum, so attending this workshop helped me figure out. And then part of the workshop was where an actual teacher was showing how she does it in her classroom so that helped me more as to how I could do it in a classroom setting.

Additionally, learning about different activities led Regina to develop student stations to introduce the content on optics and photonics to both below average and average students. Regina described the stations:

> So there were different stations, and each one was different geared towards a different part of the content, and they were trying to answer those based on working with doing. Each station was about, like, 15-20 minutes. So it took me two days to finish that because there were about four stations, and at the end we would come up together and would try to figure out how a specific thing was working. On one station, they would go and they would like through the specific lens and try to see what kind of image it was forming and why it was forming. The second station, they would go and they would see, like, the activity where we were outside and we were trying to figure out—there was a mirror on the wall and we were going outside so we could see the angle of reflection. That was the other activity. And in the third one we had the problem-based learning module, so they were trying to answer that. And then in one of the stations there was a web-based website that they were trying to look at and find the answer.

Because, as Thomas pointed out, the North Carolina Essential Science Standards have recently incorporated content for sixth grade on energy that the light emitting diode engineering curriculum module from PBLTPD program addressed, Thomas used the resources and inquiry approaches in his classroom:

> Well, the LED versus the incandescent bulbs was kind of a lead off into the energy efficiency. We really didn't. . . I didn't give a lot of prior information to the students on that. It was set up so they could kind of learn on their own what we were doing about energy efficiency and part of it was how to set up an experiment also—not too much constructivist learning yet. I mean, we were thrown into this new curriculum this year, and it was basically survive. Now after this year, I'm going to be able to add some more stuff this next year because I found out what worked, what didn't work, and some things I need to improve on. So this was a difficult year trying to implement a brand new curriculum with no. Other than things like. . . I'm glad I went to this photonics workshop because it gave me some materials to use.

Ann explained how she was able to modify the optics and photonics curriculum by using inquiry approaches to engage the learners from sixth, seventh, eighth grades, and kindergarten:

> I think providing the materials and allowing the students to investigate on their own and make their own observations before giving any kind of instruction or any kind of knowledge-based teaching. Certainly in my kinder class, it was more exploratory; it was giving them the tools and materials, which I did have in that setting because it's a wealthier situation. It was more exploratory whereas in sixth grade there was some exploration, but there was more structure in our school right now. So more

> professional development on exactly how the structure of a PBL is supposed to be good for realizing the potential of teaching children using these approaches allowing students to do more experiments in the class over time.

Cathy shared how she applied what she learned about inquiry-based learning beyond PBLTPD content:

> I did research a lot about, especially the problem-based learning (PBL) style of learning. Since the workshop I've started an elective class called Engineering Fundamentals, and with that approach, I wanted it to be that style of PBL. Finding various resources like teachengineering.com has a lot; I just really liked that style. I think that it works well with students wanting to learn more not just about content but wanting to utilize the content and make it real to them.

Like Cathy, Angela sought out more information about PBL. Specifically, she took a class to learn more about the PBL teaching approach to incorporate into her biology classroom to develop students' inquiry skills:

> Well, I also went to a PBL workshop to learn more about it and learn how to implement it, and I'll just give you an example of something that we do. For our skeletal system in anatomy, they have three bones, which are a skull, ulna, and tibia, and from those three bones, they have to figure out the race, the height, the age, and the gender of the person with just three bones. So of course, their first reaction is they look at me like, "Ms. Cox, what are you talking about? There's no way we can figure all this stuff out!" But I told them, "Yes." I give them slightly a bit of

> information, but they have to look on the Internet and then they have to put it all together and by the end, you know, they're looking at things differently. When they see people, they see the shape of their forehead, you know, it's more than just "Oh, it's just a skull. It's a nice little thing to look at." So, that's one thing they have to do measurements and they have to do calculations to figure out the size and use the shape of the eyes and different things, and the nose to figure out the ancestry of the person.

Incorporating inquiry-based and problem-based learning is not without challenges. George highlighted obstacles teachers may encounter implementing PBL:

> Being exposed to the problem-based learning approach intrigued some teachers to research this style of teaching further and resulted in teachers creating classes focused on these skills, an Well, the biggest one is time. {Laughter} Because in problem-based learning, you don't have the time to. . .You don't want to stop an activity, you want to work through the whole project. That's when the students learn. Again, time is the biggest constraint. People also confuse problem-based learning with project-based learning, and problem-based learning, you're given a set of problems and you tell the kids to go. In project-based learning, you're developing a project or a product by the end of it. That type of delineation, I think I need a little bit more professional development on because we are, in our school now, we're going to be getting more. We're trying to become a STEM school, and we're focusing more on engineering, so

> I guess what I'm gathering from these strategies, PBL strategies will be more important for us now—for me as an individual but for us, all teachers

Overall, the findings revealed that teachers used inquiry-based and PBL strategies to teach optics and photonics curriculum as well as other science topics in their classroom. Their experience modeling inquiry-based and PBL strategies also left some wanting to learn more about inquiry-based and PBL which led a few to seek more information by taking a course, researching it more on the Internet, or seeking more professional development on PBL strategies.

Web-Based Technology Implementation

Overall, the teachers did not use the web-based learning technology environments (Moodle® and Elluminate®) innovations in their classes as much as the optics and photonics content and inquiry strategies. For these teachers, it was their first introduction to these environments in a science teacher professional development program and their first exposure to how these learning environments could be used as an instructional tool in their classroom or as a collaborative learning space for teachers. Many of the educators were developing a working knowledge of the multiple web-based technology tools and determining what would work for their classroom.

Indeed, some educators found the innovation incongruent with their learning styles and beliefs and did not attempt to use them with students in their classrooms; other noted not having sufficient resources to support their use. A few participants saw the various web-based technology tools as the future direction of education and used the workshop experience as a basis for continual learning, implementation, and exploration after the workshop. Others noted they decided to use them when opportunities or mandates within their school district promoted the use of the tools in their classroom or as mode for professional enhancement. As such, this section presents how teachers used these web-based tools.

Teacher Use of Web-Technology Technology

Wikis and simulations. Science teachers found the simulations and website resources useful in demonstrating science phenomena to students. As noted by Susan, "The activities like "Mirror, Mirror, on the Wall," that was angle of reflection again, but that was one I use now and used for two years in a row. Websites—there's an interactive angle of reflection website that I now use with the kids." Janet found tools and resources beyond what was presented in for her chemistry class:

> The only tool that I could say that I still use today or that I've used is the wiki and my kids probably have once a year after that particular professional development they posted a blog or something on the wiki I created. But that was the only time I ever did that. Well, um, those websites that we used helped me to find other information that I needed in my classroom. Like I recall being exposed to that and I was just able to search it and I found other resources for my Chemistry class using that. And so although some of the stuff wasn't discussed during our workshop, I was able to find some things that fit my Chemistry class to use it for my classroom. If I hadn't been exposed to it when I was there, I probably never would have known.

The teachers not only used the web-based tools to support instruction, but also to support teaching and administrative responsibilities. Cathy found wikis to be a compatible, useful, and effective resource for teachers in her school to use, for example, to manage a flex time period in the school schedule to organize student work assignments in a central location:

> So I decided I'd make a wiki page and be able to have every teacher be able to put in their assignments for that week or that day so that every other teacher can say, "Who do you have for a teacher?" and they can just look on the wiki page and figure out what that student needs to be doing instead of sending out these huge email strings to everyone. So I guess I kind of took the knowledge of wiki pages and utilized it for the school.

In short, some teachers did use the virtual learning environments in their schools, but more would use the simulations, websites, and wikis to support their teaching and administrative responsibilities at their schools. What may have influenced the use or nonuse of web-based tools will be discussed further in the next chapter.

STEM enrichment programs. Even though teachers did not have any direct and immediate use of web-based virtual learning tools (i.e., Elluminate® or Moodle®) within their classrooms, implementation of web-based tools did occur in other settings. Cathy indicated that she did not use Elluminate® or Moodle® in her class but did use it during the two years she worked in the National Science Foundation Photonics Leaders II student year-round program. She used these environments to teach high school students photonics content and developed her skills that later prepared her to be a teacher leader at her school when her school adopted Edmodo, a web-based tool with features similar to Elluminate. The quote below highlights her implementation of web-based technology in a different setting:

> So in Photonics sometimes we would have weekend, Saturday sessions where students wouldn't have to all meet face-to-face but would meet online in an Elluminate setting, and so it was an easy way to either refresh or introduce new content to them when they're all there. We did, in particular, a lesson on. . . (Oh, my gosh, it's hard to remember this). I did a lesson on robotics and photonics? Gosh, it was so long ago. A particular lesson, I don't remember the title of it, but we did. It was about three hours or so, and every student had to check in. And I would have specific points where I would ask them to answer questions; I would call on specific students to answer questions. Most of the time, the technology was working correctly and they could use their headset and answer each other. We would use breakout group technology where specific groups of students would go to virtual locations; there they would collaborate with each other; do research; make a mini-slide presentation of what they researched, and everyone would share what they learned with each other. And then the other students would have an opportunity to ask questions and make comments about what that group of students' research. It was really neat. It was the same kind of thing you would do in the classroom, but it was all at your own home, so it was very convenient, and they still learned just as much as they would learn in a classroom.

In brief, this excerpt revealed that STEM enrichment learning environments provided a space for Cathy to learn more about the web-based tools introduced in the professional development program. Her successful use of the tools over time with students introduced her to the potential applications of the environment with students. These experiences provided her with concrete examples she could share with her colleagues, which supported her serving in a leadership role at her school during adoption of web-based tools.

Student learning and parent engagement. Teachers also used web-based tools to promote student learning and parent engagement. For instance, Paul, who had previous experience using Moodle ® with high school students, shared that his participation in PBLTPD provided him more strategies that he could use in his classroom for instructional and assessment purposes. Here he describes his use of Moodle® to address different instructional and assessment needs in his class:

> Well, I've used somewhere I just show online or interact with one or two other people online so that they could use it as a demonstration in my classroom. In other things, I've done it where they did their work outside the classroom on their own computers. Then I've had some where I've put stuff online, where they had to. . . I've tried different things from the information being online and they would do what you would consider a worksheet to make sure they actually went through the information to putting tests and quizzes online. Or say we would start a unit on anything; I would put up a pre-test, or "These are the kinds of questions you're going to have to answer"

> and give them areas they can look at or links to look at to help them with the areas and the questions I'm going to be asking.

Teachers also acknowledged the flexibility that web-based environments like Moodle® and Elluminate® provide educators to meet the diverse needs of learners. George, who worked in a one-on-one school district, had been inundated with district support and resources after his initial introduction to Moodle® and Elluminate® in PBLTPD program. He used Moodle® extensively with students, parents and other teachers in his school and district. He indicated that his experience with PBLTPD program and Photonics Leaders II student program provided him the confidence needed to be a leader in his school district. George used Moodle® to provide content, download videos, and extend inquiry learning in his class:

> But I am able to put Moodle® courses and small snippets of lectures on Moodle® where the kids can go and actually click on my course or see videos that I put up on the course. Again, of the content. And what that allows us to do is put the content there on Moodle and the kids can get it any time. We have more freedom, the freedom to do more things in the classroom. They content off line, and when they're in the classroom, we can do the extend part of the 5E program.

George also provided parent access so that could discover what students were learning and doing in his course. Additionally, George shared these approaches with teachers in his school and district to foster collaboration among educators on Moodle®. In general, teachers who were exposed to more student-centered applications of Moodle® and had extended learning with the web-based tool outside of PBLTPD gained confidence in using Moodle® to share with students, parents, and teachers to support teaching, learning, assessment, and parent engagement.

Research Question 3: What facilitates or impedes science teachers' implementation of Photonics Blended Learning Teacher Professional Development innovations into their classroom?

This section presents findings relevant to research question three. Table 4.5 summarizes the facilitators and barriers as well to implementation. Different factors influenced teachers' implementation of the three innovations presented in PBLTPD program. Rogers's (2003) diffusion of innovation theory, particularly the innovation decision process and attributes of innovations, was used to describe what factors may have contributed to facilitating or impeding teachers' implementation. Specifically, I consider what contributed to reducing or maintaining the teachers' uncertainty in regards to the innovations presented in PBLTPD.

Table 4.5
Facilitators and Barriers to PBLTPD Implementation & Rogers's Theory's Attributes of Innovation

Innovations	**Roger's Diffusion Theory**	**Specific Examples**
Content	**Facilitators**	
	· Relative advantage	Social & economic value
	· Compatibility	Belief, experience, need
	· Trialability	Time to learn
	· Other	Motivation
	Barriers	
	· Complexity	Difficult to understand
	· Trialability	Experimentation time
	· Compatibility	Content does not meet need
	· Other	Resources, money, & time
Inquiry	**Facilitators**	
	· Observability	Groupwork, learning, & seeing
	· Trialability	Hands-on experimentation time
	· Complexity (low)	Not difficult to understand after doing it
	Barriers	
	· Complexity (too hard)	Implementation difficult
	· Trialability	Time needed to experiment and learn
	· Compatibility	Did not meet teaching need or belief
	· Other	Low confidence, resources & money
Web-based technology	**Facilitators**	
	· Compatibility	Instructional/managerial need met
	· Observability	Visibility in school, district or county
	· Trialability	Informal science program practice

Table 4.5 cont'd

Barriers		
·	Relative advantage	Low social & economic value
·	Trialability	No time to test and learn
·	Compatibility	Belief not met
·	Complexity	Difficult to use
·	Observability	Not visible in school context and

According to Rogers's (2003) diffusion of innovation theory, an individual's perception of the innovation's attributes influences their overall rate of adoption: relative advantage (what are the social and economic advantages of innovation), compatibility (how consistent is the innovation with existing beliefs, past experiences, and potential needs), complexity (is the innovation difficult to use or understand), trialability (what opportunities are available to experiment with the innovation), and observability (what results of the innovation are visible to others).

Facilitators and Barriers of Teacher Implementation

This section presents findings related to the facilitators and barriers for a) optics and photonics content; b) inquiry-based strategies, and c) web-based technologies.

Diffusion of optics and photonics content. All but two of the teachers implemented the photonics/optics into the classroom initially after the professional development. Currently eight of the fifteen teachers are still using photonics/optics activities in the classroom or other avenues. For the implementers of the optics and photonics content, relative advantage (social or economic value) and compatibility of innovations were found to be important. Participants in the program wanted to learn new content to take back to classroom. This desire is represented in Ann's statement: "I was new to physical science. I had very little experiences other than taking a Praxis in order to be qualified to teach middle school science and was very interested in making the classroom more interactive and having the content knowledge."

Ann also shared that this workshop was of higher quality than she had before, and it provided her resources she could use, information that expanded her vision of teaching, and exposure to real science applications that she could take back to her school. Overall as indicated below for Ann, PBLTPD surpassed her past professional development learning experiences:

> It's head and shoulders above anything I've done, I think. I just. . . It just totally opened my eyes to new possibilities. I saw opportunities for kids learning in ways I've never seen before. The quality was fantastic; the time was good; the amount of time spent on task was good; there was not a moment of time, in my opinion, wasted.

Ann's motivation to use the content was based on her positive experience that included learning new information in a relaxed, organized, and fun environment that gave her a real experience to take back with her to facilitate instruction in her own class: "Well because I had fun doing it in the workshop; it's like because I had a positive experience myself that, and it was real for me, and I had learning from it, then going back and doing that with my students, I knew they would enjoy it and they would gain as much or more than I did." Ann reflections regarding the content's trialability and observability experience reduced any uncertainty she may have had regarding the use of the optics and photonics content in her classroom.

Support and recommendation of the school administrator and curriculum changes also supported teachers' use of the content but were not nearly as prominent in the data as the compatibility, trialability and relative advantage attributes of the content. It also supported teachers' need for professional development to learn more about light and energy concepts.

Findings in the study showed that not every person implemented the optics and photonics content into their classrooms and some are no longer using the optics and photonics content and activities. Some teachers indicated they did not use all of the content because they did not feel confident with teaching it. They had discussions with students to inform students about the content, but did not incorporate a full-fledged activity integration. In these instances, concerns related to complexity of the content and the need for additional experimentation (trialability), and time to learn the content was a need for the teacher. Of this, Angela shared:

> Well, I don't really do physical science, but actually in my anatomy class, I was able to put a little bit in there. That's not a strength of mine either. I'm not good in math, so the physical science stuff just doesn't come together. It allowed me to venture out into that a little bit; I didn't go far, but I did some of it in my classroom even though I'm more of a life science teacher.

Holly indicated that she no longer teaches sixth grade and has not used the materials since her new appointment. While, Chris indicated that not having the materials to do the activities was a barrier:

> In some cases, I just didn't have the material to do them. I understand that I can ask for things from The Science House, but in a time crunch when I come up to the subject, I just didn't feel like I had enough time to get the stuff to me in the time to do it for the class. I didn't plan ahead in some cases, so some of the things that were offered to me, I did not put in a request soon enough to have them sent to me or pick them up from The Science House.

Ann and four other teachers mentioned a similar reason; in Ann's words, "not having the materials necessary to conduct the experiments in my grasp was a deterrent, and it was difficult to get some of those materials." Although resources were available to teachers to checkout for The Science House, money and lack of resources were noted as prominent factors prohibiting implementation.

Diffusion of inquiry-based/problem-based strategies. The teachers used inquiry-based strategies to teach the optics and photonics content or used it to teach science in general. The experiences of Regina, Ann, and Susan provide a lens into how the design of the workshop provided teachers opportunities to do the activities, partner with other teachers, and experiment with the activities, and build a basis and foundation to facilitate use in their own classroom. These accounts provide examples of teachers with different teaching backgrounds and years of experience. The actual learning experience for teachers may reduce their uncertainty about using the approach and facilitate their use in the classroom. For example, Regina used a lecture format before the workshop to teach concepts related to light. Her exposure to the content and practical strategies for implementing the activities by another teacher, and time to actually do the activity reduced her uncertainty regarding the complexity, trialability, and observability of the innovation. As documented below:

> Yes. Because it was part of the curriculum, and usually science education involves hands-on learning, and it was a good opportunity that was being offered because sometimes what happens is you go to a workshop and it's geared towards high school, but this workshop was aimed at high school and middle school, so I thought it would be a good opportunity to attend a workshop. I came to know different things that I could do with hands-on learning, but earlier when I used to teach this curriculum, it was more like lecture and it was more like showing visuals, but I did not do many hands-on activities that could go with the curriculum, so attending this workshop helped me figure out. And then part of the workshop was where an actual teacher was showing how she does it in her classroom so that helped me more [to see] as to how I could do it in a classroom setting.

Regina's account is not representative of every case, but provides an example of what contributed to her using more inquiry-based lessons versus didactic instruction. She wanted to teach content related to optics and photonics differently, and the inquiry activities were supportive of her achieving that goal. In the next example, Susan comments on how the information was clearly presented and actually doing the hands-on activities on electronics and other topics helped her with teaching the students. She also explained how the workshop experience supporter her use of inquiry-based strategies with middle school students and how these activities reinforced important scientific investigation skills with the learners:

> Well, what you all did was made it very understandable. We got to do it hands-on. You know, with teachers, I think, especially with science, sometimes people are a little hesitant because they don't know if they were going to be the same result is going as what you're expecting. And so to have the opportunity to do it ahead of time, then you know what to expect. It's like the circuit, building the LED circuits. If you've never built an LED circuit before, and then you think, "Oh, my gosh. The students are going to do this and what if it doesn't light? And how am I going to answer their question? Maybe I just won't do it. I'm too timid." Some people are thinking, "I'm too timid." That's not me. I tell the kids, "Sometimes things, they work different sometimes and you just try again." It's that investigation part of that as to why it didn't work that I think is important for them to think through and get a learning experience out of.

The final example demonstrates how the PD design of having teachers working in groups and collaborating with their group members to discuss activities and explain the content was another useful way of demonstrating to teachers the actual inquiry process and what students would think, feel, and experience in an environment that fosters inquiry learning with unfamiliar content. This approach contributed to reducing any uncertainties regarding use of the inquiry-based strategies with middle school students and addressed teachers' need to incorporate more inquiry-based activities in a compatible way. The learning time with the instructional approach allowed teachers to observe and experiment with the innovation, which facilitated increased use of the strategy. Susan shared that:

> There were times when the content was a little over my head; evidently I've made really good friends with a high school physics teacher and she would kind of bring things down to my level once in a while because I'd always been an elementary teacher and she was a high school physics teacher, so partnering with someone like that took away some of that difficulty.

These examples reflect how the complexity of implementing hands-on activities was reduced through immersion with the inquiry learning activities. Having the time to experiment and model the various skills was helpful in reducing any uncertainty towards using the teaching strategies in the classroom, and being able to see the impact of the learning experience and its impact on teachers' instructional methods. As noted by Angela, some teachers needed more time and support in implementing inquiry activities (trialability) into their class:

> More hands-on, I need more time because we were introduced to so many things, so it's not time-practical, and like another follow-up would have helped. I needed hands-on because it's not something that was intuitive to me, so just more time with me hands-on and use it, and just talk to more people that had used it and get more comfortable with it, so that's something that I would have needed and I would have enjoyed doing, but there are time limitations.

Susan explained that not being able to finding activities that were applicable for middle school students regarding the problem-based learning modules as a factor limiting implementation into her class:

> I think the one that you used when we were there was more high school-related, and I needed to get something that was more with my sixth grade, and you know when they come in to me, they're still elementary. They're like just out of fifth grade, so I needed to get something that would—a problem that they would relate to a little easier and then have the Science to go with it, which direction to go with it.

Paul also noted that the content did not address the standard course of study as being a deterrent for implementation: "Um, the things that were the biggest deterrents: one, getting the funds from the school to purchase more, and that's basically because it doesn't seem to match what was the standard course of study or now the Essential Standards." This example reflects activities shared were not compatible with some teachers' curriculum needs and stalled implementation the classroom.

Seven teachers noted other limiting factors (i.e., lack of materials and funding) for implementation of inquiry-based activities. As stated by Regina, "The only part was I had a big class, and I did not have as many, so I figured out a way where I could set up different stations and we repeated through different stations so that everyone would be able to use all the parts of the different activities that were there." In summary, factors that prevented teachers' implementation of inquiry-based activities included trialability (needing more time to experiment with the activities and strategies); low compatibility (not meeting a required standard for a grade level); and complexity (appearing too difficult to implement). Other factors that emerged were a low sense of confidence or self-efficacy towards integrating strategies successfully and teachers needing more resources and support for implementation to occur.

Diffusion of web-based technology. The implementation of web-based technologies (i.e., websites, simulations and virtual learning environments) was influenced by the compatibility, trialability, and observability attributes of innovation. Teachers found wikis and simulations to be tools that met their instructional needs and used them in their classrooms. For example, Cathy saw wikis to be compatible, useful, and effective resource for teachers in her school to use. As shared earlier, she used the tools to manage administrative needs within the school for organizing student work assignments into one central location:

> So I decided I'd make a wiki page and be able to have every teacher be able to put in their assignments for that week or that day so that every other teacher can say, "Who do you have for a teacher?" and they can just look on the wiki page and figure out what that student needs to be doing instead of sending out these huge email strings to everyone. So I guess I kind of took the knowledge of wiki pages and utilized it for the school.

The opportunity to further explore Elluminate or Moodle in different settings through STEM programs, graduate courses, and professional developments gave teachers more time to learn about the web-based tools and adopt them later based on the changes in their school context or social system. Cathy shared how she used Elluminate and Moodle for two years in the National Science Foundation Photonics Leaders II student program at The Science House and how it prepared her to be a leader at her school when her school adopted Edmodo, a web-based tool with features similar to Elluminate. The quote below highlights her out-of-school experience and what she did with the tools that equipped her to lead at her charter school with concrete application examples:

> So in Photonics sometimes we would have weekend, Saturday sessions where students wouldn't have to all meet face-to-face but would meet online in an Elluminate setting, and so it was an easy way to either refresh or introduce new content to them when they're all there. We did, in particular, a lesson on. . . (Oh, my gosh, it's hard to remember this). I did a lesson on robotics and photonics? Gosh, it was so long ago. A particular lesson, I don't remember the title of it, but we did. It was about three hours or so, and every student had to check in. And I would have specific points where I would ask them to answer questions; I would call on specific students to answer questions. Most of the time, the technology was working correctly and they could use their headset and answer each other. We would use breakout group technology where specific groups of students would go to virtual locations; there they would collaborate with each other; do research; make a mini-slide presentation of what they researched, and everyone would share what they learned with each other. And then the other students would have an opportunity to ask questions and make comments about what that group of students' research. It was

> really neat. It was the same kind of thing you would do in the classroom, but it was all at your own home, so it was very convenient, and they still learned just as much as they would learn in a classroom.

George acknowledged that he has taken 20 different seminars on web-based tools and that he uses Moodle to house 70 to 80 percent of the content he teaches to extend his students' learning experiences. His school district was a one-to-one school that supported his continued exploration and use of web-based tools. For George, having previous experience with Moodle and Elluminate provided him with knowledge of systems that his school district was now promoting; this knowledge placed him at higher social level and gave him a relative advantage over his colleagues who had no prior experience with the technology. In a way, he could be thought of as an early adopter in his school district because he shared his learning experiences and concrete examples with teachers interested in using the tool and informed parents by providing access to virtual learning space.

Several teachers began to apply their knowledge of web-based technology once their school system and administrators endorsed the use of tools for instructional and professional purposes. For example, Angela noted that she developed an online course to teach a biology class that she once facilitated for teachers face-to-face due to her experience in PBLTPD and STEM program. Although web-based tools were not used in her classroom, her first introduction to these web-based tools was in PBLTPD, and that experience fostered a working knowledge she could use to set up an online course within the school district.

To sum up the findings related to factors facilitating teachers' use of web-based tools, compatibility and trialability was prominent in teachers implementing web-based tools, and the visibility (observability) of the tool in their social system was critical to teachers acting upon the knowledge they acquired from PBLTPD. Although teachers did not use the virtual learning environments in their classrooms, they did use the simulations, websites, and wikis to support their instructional, teaching and administrative responsibilities at their schools and found alternative settings to use the web-based tools.

Barriers impacting use of Moodle and Elluminate were largely related to teachers' perceptions of the web-based technology. Science teachers' perceptions of the utility of web-based technology tools in the classroom varied. Participants' feelings of discomfort and distress with using technology to teach students suggested that the technology appeared complex and incompatible with the participants' current teaching beliefs. For instance, Lynn shared:

> I did not use any of the Elluminate sessions. I just wasn't….I wasn't comfortable when we did them, but I wasn't using them every day, so I did not go back and use those. I did feel a level of comfort because of them, and I took a class in the fall at State that was on technology, and so I have used a lot more web-based tools since then.

Although there was initially a struggle with using these forms of technology, Lynn's feelings about these web-based technologies changed over time. However, other teachers' views did not change over time. For example, Molly was distressed with the thought of using technology to teach children online and expressed concerned that students would not learn personal skills needed in face-to-face spaces. She communicated that “technology is only as good as the people who are operating it, and if you are so young, and technology is now so young, that they haven’t learned any of the other things that they need to know about how to control it, how to not be bullied by it, [and] how to not abuse it.”

The exposure to web-based technology was met with different responses from the participants. Several educators were informed of the vast applications of web-based technology in PBLTPD program and continued their investigation of these tools and environments by taking professional development courses, entering online graduate programs, working in programs that supported developing web-based technology skills, and exploring different forms of tools introduced in their districts. For example, Timothy’s introduction to the web-based tools made him aware of additional areas in which he could acquire professional training, and he sought out opportunities that enhanced his knowledge of web-based technology tools:

> It was, again, the photonics [that] opened the door and said, “Oh, these things are out there. I better go learn about these,” or “They’re interesting—I need to learn more about them.” I did, like, six three-week courses or something, and they all used Moodle. So I learned, “This is how you submit your lesson,” “This is how you collaborate asynchronously; this is how you synchronize your chat room,” and these are things that. . . I was introduced to Moodle with the photonics; didn’t even know it existed. I did a year and a half of online courses with NC Learn. Working with

> Elluminate over the summer with those sessions that we did, which was really exhilarating...when you're running a couple of rooms and you've got kids going to different rooms, answering different questions, coming back and doing whiteboard presentations. It really is great just watching and listening to them collaborating on their own because they're a lot less. . . I think they're a little less restricted . . .I mean, you can pop in and listen in. It's not, your physical presence isn't intimidating or anything, so you can learn a lot from them.

Two teachers attempted to use Elluminate internationally with schools in Japan and Russia, but their plans were not successfully implemented due to technical difficulties, scheduling conflicts, and time. However, the introduction to web-based technology increased participants' awareness of emerging technology applications for the classroom. The decision to explore them further after the workshop varied according to teachers' school context.

Based on the findings of low implementation of web-based technology tools into the science classrooms and schools, it appears that teachers did not see a relative advantage in using the tool because either no potential need of the adopter was being addressed by the addition of the tool (compatibility); there was not enough time to use or test the resource (trialability) to make a better assessment; or there was limited observation (observability) of convincing results or capability prevented implementation. Teacher participants encountered difficulty with the online part of PBLTPD (complexity), which contributed to increased uncertainty and lowered their interest to implement into the classroom. Most of the participants were seeking additional information about the strategy and its implications to their environment.

Holly's remarks reflect her impression of the online component: "The discipline to get involved in the online part was a challenge for me; it really was because the professional development itself was very hands-on and interactive; that's my kind of learning. The online part of it was much more difficult for me to engage in." Molly was stressed by the impersonal approach that technology presents in the education environment and feared that it would do more harm to students then any benefit; as revealed when she said, "That distressed me. She was very vehement about that, and whether or not it's true or not, I think that will be the real downfall of education. I just wanted to say that."

Additional concerns or challenges teachers faced were related to their local context and resource availability as well as technical difficulties (i.e., outdated equipment, login, stress or anxiety, incongruence with teaching and learning style). For Susan, experiencing technical difficulties contributed to increased uncertainty regarding the complexity of the technology and low relative advantage of using of web-based technology in her class. She indicated outdated computer equipment and computer login problems as challenges:

> Probably the biggest challenge was for me to be able to get online and talk to you all in those meetings. That was a challenge for me just because my computer is old and not very updated and, you know, I'm not very technology-minded but I'm trying to get better, so I would say that was the biggest challenge.

As noted by Lynn, technical difficulties and log in issues were encountered using web-based technology: "We were there together and whatever technical difficulties could be ironed out then…that and how teachers implemented materials, information, and skills learned from PBLTPD program." Janet indicated a level of comfort with technology as she practiced using the technologies:

> You know, I just don't remember anything that was challenging except trying to do the Moodle stuff in some cases because it was new to me. But after I did it a couple of times, I kind of got a greater understanding. It just took some time to get used to it, speaking on the Moodle. Maybe getting logged in a couple of times was a challenge.

This section presented findings related to facilitators and barriers towards implementing PBLTPD strategies into the classroom or other locations. The next section provides a summary of the study findings.

Summary

In this chapter, I presented the findings to the three research questions of this study, which provide insight about teachers' learning experiences in PBLTPD program and their decisions to adopt or reject innovations.

Research question one examined teachers' experiences in PBLTPD program. The participants perceived the learning experiences as positive and beneficial, and they noted that learning occurred in a well-organized, comprehensive, hands-on, relevant, fun, and supportive learning environment. The participants reported that they learned new optics and photonics content, acquired new instructional materials and resources to teach the optics and photonics content, learned new inquiry-based and problem-based teaching methods through collaborative activities, and learned how to collaborate and network with teachers from different science backgrounds and grade levels. They also learned optics and photonics applications, research, and career information they could use in their classroom and other settings.

While the participants learned many things from PBLTPD, they did also confront challenges with learning in a hybrid environment. Challenges experienced by teachers in the face-to-face component of the professional development were: a) digesting all the information presented in the workshop, b) translating the information learned for practical use, and c) learning in an environment with teachers from multidisciplinary science backgrounds. In the online component of the workshop, participants encountered challenges with a) technical aspects of the web-based tools (i.e., Internet connection, login problems, voice activation), b) developing a working knowledge of the web-based tools c) visualizing how the web-based tools could be used for instruction, and d) integrating the online teaching approach with their learning and teaching style of preference.

Research question two addressed how teachers implemented PBLTPD innovations. Findings revealed that participants used the content, inquiry-based strategies, and web-based innovations in different settings. The optics and photonics content was a) implemented in the classroom for student learning, b) used in professional learning communities and school districts for teacher learning, and c) employed to engage students in extracurricular learning programs. The data revealed that inquiry-based learning implementation had the following positive effects; including: a) it increased teachers' confidence, b) it provided examples for differentiation in instruction for lower levels, and c) it led to further investigation and practice with the teaching technique. Teachers used the web-based technologies, more specifically: a) wikis and simulations were used more than Moodle and Elluminate, b) teacher used Elluminate and learned it features in STEM enrichment programs, c) student learning and parent engagement activities, and d) graduate courses and professional developments through Moodle or Elluminate.

Research question three addressed facilitators and barriers to teachers' implementation of PBLTPD innovations. Overall, for content, the prominent facilitator for implementation was its compatibility with the participants' beliefs about 1) their need for ore content, 2) their value in learning new content, and 3) the relative advantage of having this new repertoire of knowledge to take back to their school. Motivation was another factor that influenced the implementation of content into the classroom or alternate setting. Teachers desired to learn more content knowledge and acquire more materials to meet their subject matter requirements. Factors found to prohibit teacher implementation were the content being too difficult to understand, not having enough time to learn the content during the learning experience, and the content failed to meet standards for assigned curriculum impeded implementation. Other factors included limited time, money and resources. Prominent facilitators of inquiry-based strategies was trialability, ease of use when learning, observing the activities work well with students and are used in their social system (observability), knowing that the strategies addressed a need of science instructors (compatibility), and ease of use (low complexity). Trialability and observability were critical in the implementation of inquiry or problem-based learning strategies. Barriers found to impede the implementation inquiry-based and problem-based strategies were the complexity of implementing the strategy in the class with students without having confidence that it could be done successfully, needing more time in professional development, and lacking of resources and money.

Lastly, low compatibility, trialability, and observability were factors in deterring the adoption of web-based technology learning management tools like Elluminate and Moodle. Wikis and simulations were more readily-used because they had a high compatibility and low complexity (high ease of use). Factors impeding the adoption of web-based tools were low relative advantage (innovation does not appear better than current strategy), trialability (not enough tie to test innovation), compatibility (innovation failure to meet a need, belief or value), and observability (no visible use of innovation within the social system). Other factors found to contribute to use and non-use included local school context, resource availability, and technical difficulties experienced with using the web-based tools.

Chapter Five presents a summary of the study's findings, implications, and areas for future research.

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CHAPTER FIVE: DISCUSSION AND CONCLUSIONS

This study explored fifteen middle and high school science teachers' experiences in PBLTPD, a hybrid teacher professional development program and the influence of Rogers's (2003) attributes of innovations on their adoption or rejection of science content, inquiry-based practices, and web-based technology approaches introduced in PBLTPD. Three research questions were answered in this study:

1. What are teachers' experiences in the Photonics Blended Learning Teacher Professional Development program?
2. How do teachers implement Photonics Blended Learning Teacher Professional Development strategies?
    a. How do participants implement photonics concepts?
    b. How do participants implement inquiry-based approaches?
    c. How do participants implement web-based technologies?
3. What facilitates or impedes science teachers' implementation of Photonics Blended Learning Teacher Professional Development innovations?

Purposive sampling was employed to recruit fifteen participants for this qualitative instrumental case study. Teachers represented nine North Carolina counties located mostly in economically distressed regions from charter, public, and alternative school settings. Semi-structured interviews were the primary data sources analyzed in this study. Archival program documents were examined as secondary data sources to provide contextual program information and to ensure trustworthiness through data triangulation. A personal reflection journal was kept throughout the study to document my research interpretations. Interviews were inductively and deductively analyzed using a constant comparative method in *Atlas.ti* (Bogdan and Biklen, 2006; Glasser and Strauss, 1967; Scientific Solutions, 2011). In this chapter, I review the key findings of the study. Next, the study's conclusions and limitations are outlined in detail. To conclude the chapter, I present the theoretical and practical implications for teachers, professional developers, policymakers and recommendations for future research.

Key Findings and Conclusions

Research question one examined what are teachers' experiences in PBLTPD? Middle and high school teachers learned new content, activities, teacher strategies, career information, how to collaborate, how to facilitate collaboration in their classroom, and gained a broader awareness of web-based technology strategies by participating in the hybrid teacher professional development. Teachers experienced challenges learning in the hybrid platform. In the face-to-face learning environment, teachers experienced difficulty with the scope, volume, and depth of content, interacting in a cross-disciplined learning environment, and translating learned content for student learning. With the asynchronous online component of PBLTPD, teachers reported technical problems related to the microphone and voice features, application of learning management systems, their distinct features, and integration of web-based tools or strategies into the classroom for instruction.

Research question two examined how teachers implement content, inquiry-based approaches, and web-based technology strategies? Many middle and high school teachers used the optics and photonics content in their classrooms, professional learning communities, and in extracurricular programs, especially during and immediately after the program. The findings also revealed that teachers used inquiry-based strategies to differentiate their instruction in their classrooms, for further investigation through participating in additional professional development programs, and as an approach to support the development of their confidence with implementing the strategy. Teachers were quite apprehensive implementing the web-based synchronous and asynchronous learning tools initially and preferred the use of simpler forms of web-based technology tools (i.e., wikis, websites, and simulations). Teachers' use of asynchronous and synchronous learning tools were limited due to incompatibility of the tool and difficulty experienced using the tool in the program or accessing it at their local school. In addition, use for some participants evolved over time with implementation occurring in schools for remote engagement of parents and students; and in informal science, technology, engineering and mathematics programs. These activities included the implementation of online synchronous tools when the communication channels at their school promoted and supported the innovation.

Research question three examined what facilitators and barriers impact implementation of PBLTPD strategies? Generally, middle and high school teachers implemented content, materials and inquiry-based activities to use in their classroom for instructional purposes more than web-based technology approaches. Based on Rogers's attributes of innovation theory, the most important facilitators were relative advantage, compatibility, and motivation. The prominent barriers for use of the content, inquiry-based strategies, and web-based technology from the theoretical perspective was complexity. Overall, complexity, low relative advantage, and incompatibility with the goals of the teachers prohibited the adoption of synchronous and asynchronous learning management tools (i.e., Moodle and Elluminate).

Teachers participated in the PBLTPD workshop because they were motivated to learn new content and strategies to engage their students in learning new science content. Though motivated to learn, they did not fully adopt all three key innovations. The findings demonstrate that teachers are more likely to adopt innovations that meet their beliefs and needs. For instance, teachers more readily adopted the content and inquiry-based approaches for their classroom than web-based technology tools, such as Moodle and Elluminate in PBLTPD. They did so because approaches reflected their individual values and beliefs about instruction and student engagement. For example, teachers' believed that inquiry-based strategies impacted learning positively so they were more likely to use inquiry-based strategies in their classroom. Teachers need to use specific content that would directly address a standard course of study, in this case optics and photonics content presented in PBLTPD. Also, school culture impacted teachers' decisions to adopt innovations. For example, teachers who were looking for learning experiences to develop their technology capacities to support effective integration into their classroom primarily worked at schools that promoted innovative integration of technology beyond the use of websites and simulations.

Blended learning teacher professional development programs have the potential to develop teachers' content knowledge, expand teachers' pedagogical skills, and introduced teachers to web-based technology tools and teaching strategies. The findings suggested that teacher knowledge and awareness of optics and photonics content, research, and career information were increased as a result of participating in PBLTPD. For example, middle and high school teachers indicated that were they learned new content related to the nature of light, electromagnetic spectrum, lasers, solar energy, electronics, liquid crystal displays, fiber optics, holography, as well as discovered real world applications from actual engineers and scientists of optoelectronics and optical sensing. More importantly, this knowledge translated to action. Teachers used these experiences for instructional purposes in their classroom to teach students specific optics and photonics content that addressed their standard course of study requirements in physical science and other science content areas.

Teachers also reported using inquiry-based instructional strategies with greater ease along with science activities to teach science content in the classroom or alternative learning settings. Some study participants, for example, shared that the inquiry-based learning approach used in PBLTPD provided a learning experience that supported their overall learning, confidence, and ability to implement the instructional strategy into their classroom, a science club setting, or professional learning community. Several of the teachers indicated that they did not have access to activities nor the materials that addressed learning objectives related to light, its applications, and current research. So, PBLTPD provided an opportunity for educators to learn and use inquiry-based instructional strategies in both face-to-face and online settings.

While teachers learned about optics and photonics content, inquiry-based instructional strategies, and web-based technology strategies in the PBLTPD, they generally did not implement web-based technologies into the classroom for instructional purposes with students. They mostly used web-based technologies for classroom management purposes or professional learning experiences, which included internal communication with educators, review boards for lesson plans, and for participation in online professional developments and webinars.

Aspects found to deter learning or barriers to implementation of PBLTPD innovations for middle and high school teachers were complexity, lack of resources, and trialability. In this study, teachers generally did not implement aspects of PBLTPD innovations that were complex or difficult to fully understand. For example, complexity impacted the use of some photonics and optics content, inquiry-based strategies, and web-based technology tools. Teachers from middle and high school levels shared that they failed to use the content because they did not understand the complex content sufficiently to teach in their classroom. They also indicated they failed to use inquiry-based strategies because they did not feel confident with leading students through the learning process or lacked the materials to support their implementation. Lastly, teachers' assessment of the web-based technology tools were mixed in regards to how the technology innovations could be used in their classroom, their overall educational benefits, and their overall ease of use. In addition, teachers encountered difficulty with accessing the online environment, using the online learning space, and identifying how web tools could be used to address specific standards in their assigned subject area.

Trialability was an important method of exposure to web-based technology learning environments for teachers. Teachers' experiences using web-based technologies in PBLTPD allowed the educators to use and observe the program features and make decisions related to use in the classroom. Resources (i.e., money, workplace, administrative support and technology specialist support) influenced teachers' decisions, especially those from economically distressed regions, to continue use of activities. The theoretical and policy implications of these findings are discussed in detail later in this chapter.

Limitations

In this study, I explored the learning experiences of science teachers in a blended learning teacher professional development, their adoption behaviors, and the impact of Rogers's (2003) attributes of innovation on the diffusion of multiple educational innovations. This study has several limitations. First, I selected teachers who participated in the Photonics Blended Learning Teacher Professional Development program that I developed with a team of STEM professionals. Selection bias affects the generalizability of the study findings. Patton (2002) recommends that the researcher keep findings within the context of the study to limit overgeneralizing. I employed this strategy by focusing on the content within the blended learning professional development research study and drawing my conclusions based on the findings.

Second, this study is bound by its context and provides information related to those in the study and PBLTPD program. The dominant data source in this study is self-reported data from the participants. Due to time constraints, the self-reported data was not verified by observations. All self-reported data is presumed to be accurate. Third, the study took place an average of two to four years after the completion of the workshop. Participants in the study occasionally experienced trouble-remembering details of their experience and implementation efforts. This may be impacted by selective memory or telescoping bias. These recall issues are inherent with many post-intervention follow-up studies. However, the advantage of investigating PBLTPD several years post-intervention provides a learning framework to understand teachers' adoptions decisions in a reformed teacher professional development program. Fourth, Elluminate, one of the web-based tools analyzed in this study, has been decommissioned and replaced by Blackboard Collaborate, a new virtual learning environment that is a similar Web 2.0 resource. Thus, the insight gained in this study may be applicable to similar web-based technologies used in the educational setting. Lastly, this study did not study the impact of teacher implementation on student learning, though the understanding of the phenomenon as revealed in this study is a necessary first step.

Theoretical Implications

Research studies that investigate the interplay in the adoption of three innovations in a professional development are lacking. Most studies that have incorporated content, pedagogy, and technology innovations generally focused on the implementation process of one innovation and not the interactive process among three innovations. Additionally, Rogers's (2003) diffusion of innovation theory has been used widely to examine the adoption of technology innovations in education settings. But there are no educational studies grounded in Rogers's diffusion theory that seek to examine how technology adoption relates to the adoption of other innovations. Technology doesn't exist in a vacuum—it is used as a tool to facilitate learning of content and effective pedagogical approaches. Thus to understand technological innovation, we must explore what other innovations are being concurrently adopted. This study does precisely that. This framework was an appropriate lens to employ for PBLTPD because it provides a descriptive tool for qualitatively examining how the characteristics of each innovation facilitate or impede diffusion through a social system.

Rogers's innovation-decision process model is the framework applied to examine teachers' decision in PBLTPD (2003, p.170). This highly, personal, interpersonal, and psychological process provides an avenue to explore teachers' experiences as they discover, process, and analyze their learning experiences with science innovations. From Rogers's diffusion theory perspective, teachers entered the workshop with different backgrounds, goals, expectations, and needs. They were introduced to the innovation during the knowledge stage whereby each teacher may develop an awareness of the innovation from the PD experience and potentially move to stage two, persuasion. During this stage, teachers form a favorable or unfavorable attitude towards the innovation and move to stage three, decision. At this stage, teachers in the workshop make an adoption or rejection decision, which directly guide their behaviors. In this study, the decision stage significantly related to teacher use or nonuse of the strategies employed in the workshop. Teachers were all presented three innovations and taught how to utilize them alone and simultaneously. The findings revealed variations among teacher use of each innovation. The next section explores the innovation-decision process in light to Rogers's diffusion theory.

From Knowledge to Persuasion

Teachers in the program moved through Rogers's five-stage innovation decision process to adopt innovations. In the first stage, teachers develop an awareness of the innovations (knowledge). During this stage, teachers want to know what the innovation is, how to use it, and how it works, which leads them to possibly seek more information about its utility. Rogers (2003) suggests that change agents should concentrate more on "how-to" knowledge to increase adoption versus developing a more thorough knowledge and awareness of innovations. This focus improves the development of teachers' knowledge in the first stage of the process and supports movement into the persuasion stage.

From Persuasion to Decision (Adoption Decision)

The next stage includes teachers' forming a favorable or unfavorable attitude or persuasion toward the three innovations. These opinions are formed by their review and assessment of the innovation in light of several factors: a) the innovation's ability to be better than the current strategies employed in their classroom (relative advantage); b) its congruence with their beliefs, values, and needs (compatibility); c) its ease of use or understandability (complexity); d) teachers' experience using the innovation for limited frame of time (trialability); and e) the innovation's presence in their school or social system (observability). These five attributes of innovation all contribute significantly in one way or another to the formation of teachers' attitudes and behavior towards adoption or rejection of PBLTPD innovations.

Rogers (2003) shares that when a person forms a favorable or unfavorable attitude towards an innovation that it does not always lead to an adoption or rejection decision. Some people may adopt to avoid an unwarranted event and there are times when a "cue to action" event causes a favorable attitude to crystallize into an overt behavior. Rogers (2003) suggests that change agents can use cue-to-action events to facilitate the development of a favorable attitude among adopters. PBLTPD introduced teachers to relevant activities and learning experiences that facilitated teachers' overall development of attitudes toward use or non-use of the multiple innovations.

From Decision to Implementation (Reinvent)

The decision and implementation stages consist of teachers' evaluating the innovations and their impact as well as considering whether to use, not use, or partially use each innovation. Teachers process these attributes of innovations as they plan their implementation and consider what to do with the innovations in their contexts. For this study, teachers used both the content and the inquiry-based strategies, but they generally decided against implementing the innovation of advanced web-based technology tools.

From Implementation to Confirmation (Evolve – Transform)

Rogers (2003) defines adoption as the continuance or discontinuance of the use of an innovation in the confirmation stage. I found the confirmation stage was a transition or link to adaptation, evaluation, and continual learning as revealed in this study. As shown, teachers in the program that implemented innovations from PBLTPD had to adapt strategies and content to meet their classroom, school, district, or personal needs. Teachers initially adopted innovations (implementation) based upon observed impact on their students; their evaluation of each innovation as they implemented it either lead to a discontinuance in use or continuance in use of (confirmation) innovations. The diffusion process continues until the innovation loses its identity in the social system (comprising stages four and five).

PBLTPD intervention was the setting where teachers came together to address the problem of developing learners' understanding of STEM content. Each participant brought his/her prior beliefs related to teaching, perceived needs/problems, innovativeness, and social system norms to learn three new innovations with peers from different economic backgrounds, personality traits, and communication behaviors. These prior experiences shaped how the teachers responded within the workshop and during the innovation-decision process, including how they use these innovations and any actions they decide to employ to continue to learn, grow, evolve, and transform into adaptive experts in their classroom and used knowledge learn from PBLTPD.

Rogers's (2003) describes an innovation as an idea, practice, and product perceived new by an individual. The innovation decision process is a process to reduce an individual's feelings of uncertainty to increase the overall rate of adoption. As discussed in this section, the reduction of teachers' uncertainty in the adoption of multiple innovations is a complex, highly personal, interpersonal, and psychological process influenced by internal and external factors within the school system, district, professional development, and individual teacher. While Roger's innovation decision process model looks at the adoption of one single innovation, PBLTPD study and professional development model complicates Rogers's model because it involves the concurrent adoption of three innovations. Figure 5.1 displays how PBLTPD approach expands how we need to look at the adoption process when multiple innovations are prescribed.

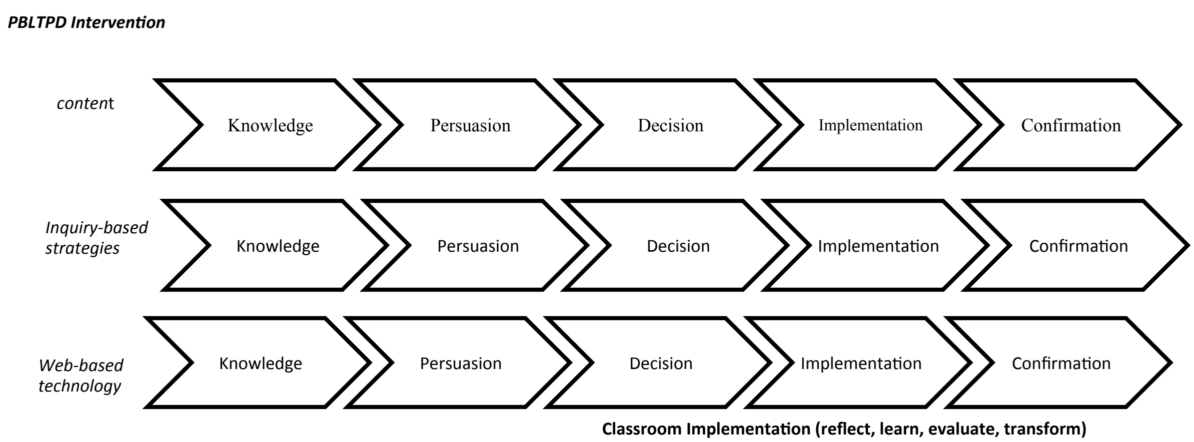

Figure 5.1 PBLTPD Innovation-Decision Process

NOTE. PBLTPD innovation decision process is the process whereby three different innovations are incorporated within one learning intervention with teachers. The innovation-decision process is the process through which an individual (or other decision making unit) passes through first the knowledge of innovation, to forming an attitude toward the innovations, to a decision to adopt or reject, to implementation of the new ideas, and to confirmation of this decision.

In addition to the other factors that may influence teachers' decisions to adopt or reject innovations, there is an interplay during the innovation-decision process. PBLTPD's successful and full implementation results from interactions of the stages of different innovations. Figure 5.2 displays the complex interaction within the innovation-decision process, other factors, and communication channels that contribute to overall adoption. The question of what influenced teachers not to implement an innovation and what factors facilitated use by teachers produced interactions as shown in Figure 5.2 below, which outlines the nuanced adoption process. The figure also display decisions that may have occurred in PBLTPD innovations' implementation as well as adoption options that may support sustained use or discontinuation.

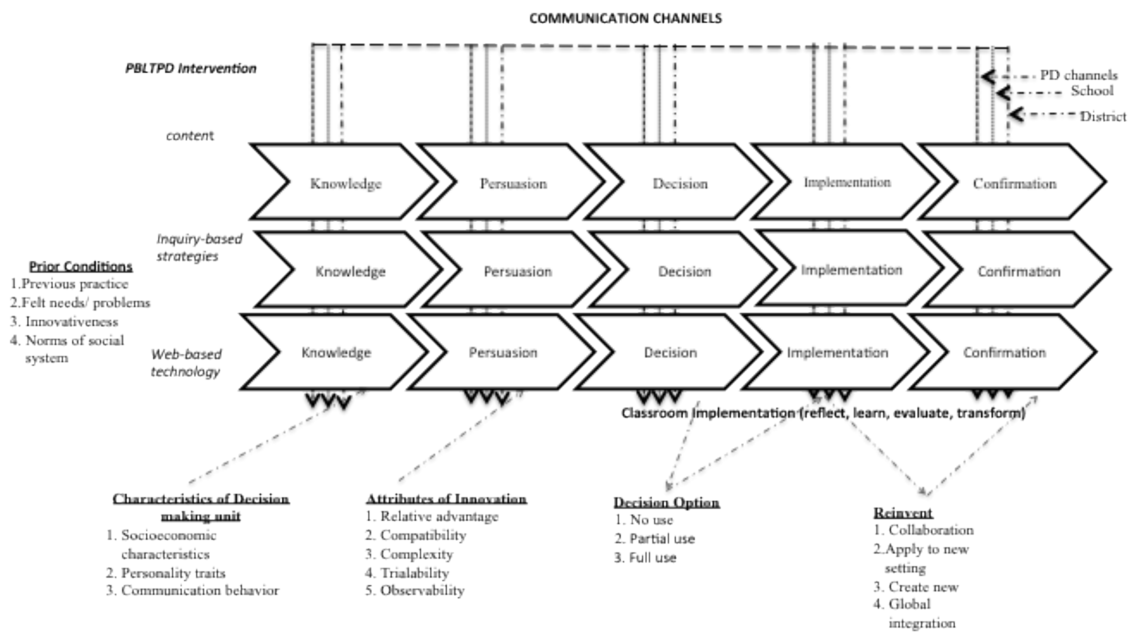

Figure 5.2 PBLTPD Interplay of Multiple Innovations and Rogers's Diffusion of Innovation

NOTE: The innovation decision process of multiple innovations is the process through which an individual or decision making unit simultaneously passes through first a knowledge of multiple innovations, to forming an attitude toward the innovations, to a decision to use or not use the innovations, to reflection of the innovations, to evaluation of the innovations, to ongoing application of innovations to new settings, new creations, or global integration of innovations, to transformation as an adaptive expert in the confirmation stage.

Figure 5.2 above summarizes the complex process of the adoption of multiple innovations by the science teachers interfacing in two different social systems—PBLTPD and their local school context. Numerous inputs and outputs in the system influence a teacher's perception and decision to use the innovations. This interaction between the three innovations in the five-stage innovation-decision process may be a mechanism for reducing uncertainty teachers may have about one or more of the innovations presented concurrently.

For example, a teacher who decides to adopt the photonics and optics content presented is more likely to use inquiry-based strategies to teach photonics and optics contents than a teacher who does not adopt the content. In contrast, a teacher who does not adopt the photonics and optics content and adopts inquiry-based strategies will use it with other content.

Implications for Policy

The President's Council of Advisors on Science Technology (PCAST, 2010) report calls for the identification and preparation of the best and brightest science, technology, engineering, and mathematics (STEM) educators to equip and inspire students to pursue STEM over the next decade. Findings from this study revealed that in-service teachers from both economically distressed and least economically distressed areas are eager to participate in quality content-focused professional developments and are in need of more quality, innovative STEM learning experiences to inspire their students. In fact, a more focused attempt is needed in the economically distressed regions of North Carolina. The main reason for the great need of these learning experiences is because teachers currently are not receiving on relevant science, technology, engineering, and mathematics content professional development in their districts. Policy efforts for STEM education must address the current needs of in-service teachers to insure that generations of young scientists, mathematicians, engineers and technology specialists are exposed to cutting-edge STEM learning experiences that nurtured their enthusiasm, problem-solving skills, and preparation for further exploration.

More work on the policy level can explore the utility of science teacher professional developments that pair economically distressed and least economically distressed counties in professional learning communities to address content, pedagogical, and technological needs of all students, especially underrepresented minority students in the STEM areas. This approach will allow for best practices to be shared, practiced, and implemented in different settings from the lens of educators' expertise with guidance from researchers. These learning exchanges should be supported by stipends to provide incentives for in-service teachers to counteract any reason for preventing teacher participation. The learning process afforded by professional development includes a time commitment for learning in the professional development, in the classroom, and at the home of the educator for real changes to occur. Time preparing, planning, implementing, assessing, and adjusting lesson plans for implementation. Policy efforts that focus on improving the STEM knowledge, skills and attitudes of teachers from economically distressed counties, especially, as well as counties that are well-resourced can ensure that all student populations, including under-represented minorities, acquire relevant research-based learning experiences and preparation for the future.

PBLTPD used the blended learning format to determine the utility of extending a three-day workshop limited by funding, time, and resources to provide teachers from varying economically distressed counties time to continue learning. The method allowed teachers to learn content and acquire resources as well as interact with peer teachers, researchers, and the program staff remotely. Blended learning has dual benefits, for it provides numerous learning options for teachers and students. This study revealed that more efforts must be employed to meet the multiple needs of teachers from economically distressed counties to ensure continued use of research-based approaches in these schools with diverse educational needs. A blended learning professional development format with consistent support and resources is a possible solution to the highly personalized needs of educators from different settings.

Implications for Teachers

Teacher creation of STEM learning experiences for all students including URM students will require educators to demonstrate leadership and risk-taking skills to learn new instructional approaches and technology tools. Findings from the study revealed that both middle and high school teachers used the content for different purposes for varying grade levels, learning abilities, ethnic, economical, and social backgrounds. These teachers experienced some level of success at exposing students to cutting-edge content and experiential learning opportunities through formal and informal science learning settings. This study has shown that teachers should create learning environments that provide real-world learning experiences for students to develop their STEM content knowledge as well as the requisite communication, problem-solving, and teamwork skills. These learning experiences can occur in formal and informal learning settings. The ultimate goal of STEM initiatives is to make science accessible to *all* students—not just the academically-gifted—and to prepare them all to thrive in our global society. To achieve this goal, teachers will need to use more sophisticated strategies and to question their instructional decisions about learners and their learning capabilities.

In PBLTPD, teachers had to take fairly complex content and customize it to meet required science standards and the unique learning needs of their students. Such customization to manage their instruction in a way that addresses issues related to the student, resources, and their school environment. When opportunities to teach the content beyond the traditional classroom arose, some teachers were innovative by introducing students to STEM learning experiences in more informal settings such science clubs, electives, community in-school programs, and afterschool programs.

Many teachers took risks to use the content to go beyond what the standard course of study required in order to nurture students' interests in science and encourage independent exploration and research. These learning experiences generally tended to build students' interest and curiosity in science and to demonstrate science's interconnectedness to other disciplines. Such exposure contributes to developing students' confidence and frame of reference of STEM fields, to increasing their learning capacities to pursue these fields; and to providing lived experiences for them to investigate how they may pursue STEM careers in the future. Providing such opportunities to students requires additional time commitment from the teacher beyond the professional development experience itself in order to make the content and learning experience accessible to the learners.

Hrabrowski's work with minority graduate students at the University of Maryland Baltimore County calls for a more sophisticated approach to cultivating African American and underrepresented students to pursue and attain STEM doctorate degrees (Maton, Polland, McDougall, Hrabrowski (2012). His work reveals that developing an institutional commitment to address the unique learning and social needs of URM learners with an inclusiveness and supportive approach on a majority campus can meet achievable goals in STEM education. Hrabrowski's strategies were ensuring academic and social integration of learners, developing learners' knowledge and skills for STEM content, providing support and motivation for learners, and establishing systems for monitoring and advising participants through their learning endeavors (Maton, Polland, McDougall, Hrabrowski, 2012). These strategies used with graduate students can be employed in the K-12 sector, and as demonstrated in PBLTPD.

The findings revealed that teachers who implemented lessons in the informal NSF PL2 student science program with students at North Carolina State University gained skills and knowledge that supported their level of comfort and ability to employ more inquiry-based, problem-based, and technology-based learning experiences more in their classrooms or alternate settings. This demonstrates that teachers serve a critical role in students' introduction to STEM awareness of STEM fields. Therefore, teachers need to continuously enhance their adaptive expertise in their craft as professionals to meet the diverse needs of the 21st century learner.

Findings from the study revealed that teacher collaboration is essential in developing teachers' overall content, pedagogy, and technology capacities to effectively equip students for the future. Science teachers must embrace working together in professional learning communities at their schools, districts, and in expanded learning communities with industry, the university or non-profit entities to further enhance their effectiveness as professional educators. This work may require working with professionals from different core subject backgrounds to address the standard course of study and common core requirements or working with professionals with similar backgrounds. Teachers may experience discomfort working in these learning communities, but such opportunities provide real-world examples of what their future students will do as collaborative scientists, engineers, and productive citizens.

Findings from the study revealed that some of the teachers were first apprehensive about learning the optics and photonics content in the multidisciplinary learning setting because they did not know how their peers would view strategies and whether discourse would be beneficial. However, many found that by exploring and learning together with professionals with different education backgrounds and teaching assignments, they could learn content, pedagogy knowledge, and develop working relationships with each other to support their instructional and professional needs. Teachers gained useful pedagogical content knowledge when they used innovations in their classroom, had the opportunity to model and experience collaboration firsthand. Many educators in the study discovered the benefit of collaborating with professionals within and outside of their school districts by sharing curriculum resources and leading in their schools in a way that distributed research-based strategies and the optics content to teachers and students beyond their classroom.

Teachers should also collaborate at the university level with science education researchers, scientists, and engineers to stay abreast of current practices and emerging research to remain informed to shape students' learning experiences. Findings from the study revealed that interacting with scientists and engineers in the optics and photonics fields expanded teachers' awareness and knowledge. Their completion of hands-on experiments developed their knowledge of the content and ways of sharing the information with students was useful. Collaboration among teachers also provided a basis to build relationships with STEM professionals at the university level through their engagement in the workshop, implementation of strategies, through follow-up activities, and extended teaching opportunities in the informal science program. While the connection with scientists and engineers was a valuable experience for educators, many expressed a need for more access to the scientists' expertise at their schools.

In this study, teachers developed some knowledge of web-based tools, they struggled with envisioning how to implement the strategy with students. Findings from the study revealed low implementation of web-based technology tools in the science classroom. Also, ninety percent of the teachers had never used web-based technologies in a hybrid teacher professional development, and their schools were not using the technology at the time of the professional development administration. Participants decided not to implement web-based technology tools in their class due to negative perceptions regarding the utility of the tool to teach science content, feelings of distressed with using the new technology, incongruence of with teaching approach and beliefs; limited access to computers, technical problems, and lack of technical support. Another reason noted by teachers as a deterrent towards using the web-based technology tools was the limited time to experiment with the tools within the workshop and specific examples for implementation into science. However, self-reported findings did reveal that teachers whose school districts later adopted web-based technologies felt more equipped to use tools due to their learning experience in PBLTPD. Teachers used web-based technologies to organize their class assignments, assessments, grading, student reflection, group discourse, and extend the class beyond the four walls of their classroom. More work is need to support teachers' discovery of the implications of these web-based tools to effectively engage and sustain teachers.

The study showed that teachers can benefit from discovering the potential applications of advanced web-based technologies like learning management systems and virtual learning environments; applying tools in their science classroom or alternative settings with students; and observing its transformative impact on learners before it is required within the school system. This experiential exploration provides teachers an opportunity to develop a working knowledge of how the tool can be used effectively in the educational setting to meet teaching and student learning needs.

Implications for Professional Developers

This study has several applications to designers or professional developers who serve as change agents in science education reform and facilitation of teacher adoption and implementation of innovations. Findings from the study revealed that science educators look for comprehensive, collaborative, and well-organized professional learning experiences that address their teacher responsibilities and duties.

Professional developers should design and develop teacher professional learning experiences by employing a systematic and comprehensive method for surveying teachers' needs and school challenges while vetting innovations and using strategies for supporting teachers in learning, discovering, implementing, evaluating, refining and reintegrating innovations. Professional developers should consider the individual teaching and learning needs of middle and high science school teachers by surveying educators to identify their greatest practical needs in the areas of content knowledge, pedagogical content knowledge, technological pedagogical content knowledge, and web-technological pedagogical content knowledge. They must make sound decisions about delivering the professional development to both grade divisions or to only to one grade division at a time and consider its benefits and disadvantages.

Findings showed that teachers preferred working with their peers who taught similar subjects and grade levels. This information can be used to inform methods employed in the teacher professional development interventions to support the development of both middle and high school science teachers' content, pedagogical, technology, and web-technology knowledge in a complex, nuanced learning environment. Strategies should be employed to ensure that sufficient time is given to allow participants time to learn each innovation to expect full implementation fidelity of strategies into their classroom. Findings from the study confirmed that science teachers need more time to experiment and use strategies taught in a professional development to ensure use in their classroom. The integration of survey findings may result in a more productive integration of technology methods to facilitate teacher use in their classrooms (Mishra & Koehler, 2006).

When using new technology, content, and pedagogy in a hybrid teacher professional development, professional developers should employ thoughtful consideration of all three types of knowledge and issues together rather than isolation. Innovation diffusion occurs in a complex system, and designers of teacher professional developments should provide concrete learning opportunities for teachers to discover, use, reflect upon, and implement innovations in their classrooms to support teacher adoption and growth. This approach will support development of teachers' technology pedagogical content knowledge (TPCK) in science over a sustained period of time with support (Mishra and Koehler, 2006). This method will also allow teachers to learn and grow as professionals developing real products that can be integrated for instruction into their classroom.

In PBLTPD, middle and high school teachers learned content and pedagogical strategies together, but the technology component was disseminated more in isolation as a support to teachers' individual professional development needs. As a strategy to increase adoption of web-based tools, teachers need to see and experience how the web-based technology tools could be directly employed into the classroom to teach content or to expand the learning context of their classroom. With more in-depth engagement with the web-based tools, teachers could be required to develop plans of implementation for their classrooms based on their specific classroom needs. According to Mishra and Koehler (2006), there is no single technological solution that applies to every teacher, course, or view of teaching. Together with professional development designers and facilitators, teachers must be active participants in the process of learning and implementing web-based technologies into their unique learning settings for the integration to effective and useful in science classrooms.

Professional developers offering a hybrid professional development for teachers to support overall adoption and implementation of multiple innovations must create learning events to support development of content, pedagogy, and technology knowledge as well as the integration of content, pedagogy, and technology knowledge in teachers' classrooms by showing how the three are integrated throughout the learning intervention. This design strategy will reinforce the intricate connections among the three types of knowledge and the resultant transformative impact on teacher learning, instruction, and student achievement. In order to facilitate this process, a design-based approach (as used in PBLTPD) must be employed where teachers are allowed to pursue adoption and implementation of technology, content and pedagogy approaches that meet the authentic contextual needs of their classroom and learners. According to Mishra and Koehler (2006), this will provide a rich context for learning and foundation for sustained inquiry and revision that is well-suited for teachers to develop a deep understanding needed to apply knowledge to complex domains of real world practice in their classroom. Such design also facilitates Rogers's (2003) diffusion cycle by providing opportunities to move between the stages.

Directions for Future Research

This study examined teachers' concurrent adoption of multiple innovations simultaneously, but more needs to be done. Other scholars could apply Rogers's diffusion theory on simultaneous adoption of multiple innovations or Concern Based Adoption Model or User Instructional Development Diffusion theories for further investigation of the adoption and implementation process. Additional research of the complex, highly, personal, and interpersonal process is needed to understand how to best deliver reformed-based professional developments that address the diverse needs of educators and school systems in both rural and urban locations. Also, this study focused on the impact on teachers, future research should consider what impact does a hybrid professional learning experience have on student learning and achievement. For this hybrid teacher professional development design, future research could examine what trends and differences exist among middle and high school teachers' learning experiences and implementation behaviors from rural and urban settings of novel science content, pedagogical strategies and web-based technology. g Another area of future research to consider is to explore which strategies science teachers adopt in other content areas. This study examined what strategies were applied using photonics and optics content. It would be beneficial to research what strategies teachers would use to teach biology, chemistry, or other physical science subject areas. A key advantage of this implementation study is that post-intervention was followed after considerable time had elapsed. An area ripe for investigation would be a longitudinal study that follows teachers before a professional development, during the professional development, and after the professional development in short-term and long-term professional developments to fully understand sustainability of change.

Chapter Summary

This chapter presented a brief overview of the study's research approach and key findings. Theoretical and policy implications of the findings were detailed. Lastly, limitations and directions for future research are outlined. Three main conclusions derived from the data were presented: 1) Educational innovations are more readily adopted and used when they are learned by teachers in a collaborative, socially-constructed learning environment, aligned with teachers' needs and their social system; 2) Blended learning teacher professional development programs have the potential to develop teachers' content knowledge, expand teachers' pedagogical skills, and introduce teachers to web-based technology tools and teaching strategies and 3) Aspects found to deter learning or adoption of innovations were complexity, lack of resources, and trialability.

Summary of Study

Spurred by national trends to increase the achievement and skills of students in science, technology, engineering, and mathematics, their pursuit of cognate careers, and degree programs, education reformers are developing approaches to improve K-12 science education through the delivery of innovative, research-based science teacher professional development programs. This qualitative, instrumental case study examines one such program, Photonics Blended Learning Teacher Professional Development (PBLTPD). Guided by Rogers's (2003) attributes of innovation theory, this study analyzes fifteen North

Carolina middle and high school teachers' experiences in PBLTPD and explores teachers' decisions to implement the photonics and optics content, inquiry-based strategies, and web-based technology tools introduced in PBLTPD. Semi-structured interviews with participants and archrival program documents were analyzed using the constant comparative approach (Bogdan & Biklen, 2006; Glasser & Strauss, 1967).

The findings revealed that middle and high school teachers who participated in PBLTPD learned new science content knowledge, inquiry-based activities, teaching strategies, collaboration skills, facilitation skills for classroom collaborative instruction; and gained a broad awareness of the advantages and disadvantages of web-based technology strategies. The results show that teachers implemented optics and photonics content and inquiry-based strategies introduced in PBLTPD in their classrooms, professional learning communities, and extracurricular programs more frequently than web-based technology strategies. Their use of web-based technology evolved over time as they implemented it in informal science activities and through formal settings when school districts' promoted the use of the approach. Based on Rogers's (2003) attribute of innovation theory, relative advantage, compatibility, and motivation were prominent factors that facilitated partial or full adoption of PBLTPD innovations. In contrast, complexity, lack of resources, and trialability of the limited or impeded adoption of aspects of the innovations.

The findings suggest that blended learning professional developments can facilitate learning of new science content, pedagogical approaches, and web-based technology strategies to meet the needs of middle and high school science teachers. The results also indicated that teachers benefit from collaborating with peer teachers, researchers, non-profit, and industry representatives to develop real world, problem-based learning experiences for students. Lastly as evidence from the findings, to promote both learning and full adoption of innovations presented in science teacher professional development programs, designers of professional developments must not only consider the values and needs of teachers and their social systems, but also take into account the innovation's relative advantages (the economic and social advantages of the innovation); compatibility (congruence of innovation with existing beliefs, past experiences, and potential needs of adopters); complexity (the potential adopters' difficulty in using or understanding the innovation); trialability (opportunities for potential adopters to experiment); and the motivation of teachers.

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APPENDICES

APPENDIX A: IRB

North Carolina State University
Institutional Review Board for the Use of Human Subjects in Research Submission for New Studies

GENERAL INFORMATION

Date Submitted: March 30, 2013
Title of Project: Science Teachers Experience Adopting Innovations in a Photonics Blended Learning Teacher Professional Development
Principal Investigator: Pamela Gilchrist
Principal Investigator Email:
Department: Leadership Policy Adult and Higher Education
Campus Box Number: 8211
Phone Number:
Faculty Sponsor Name if Student Submission: Dr. Tamara Young
Faculty Sponsor Email Address if Student Submission:
Source of Funding (Sponsor, Federal, External, etc)**:** *If Externally funded, include sponsor name and university account number:*
RANK: Faculty: ☐; Student: ☐Undergraduate ☐ Masters x PhD; Other:

As the principal investigator, my signature testifies that I have read and understood the University Policy and Procedures for the Use of Human Subjects in Research. I assure the Committee that all procedures performed under this project will be conducted exactly as outlined in the Proposal Narrative and that any modification to this protocol will be submitted to the Committee in the form of an amendment for its approval prior to implementation.
Electronic submissions to the IRB are considered signed via an electronic signature

Principal Investigator:

____

(typed/printed name) (signature) (date)

As the faculty sponsor, my signature (or electronic submission) testifies that I have reviewed this application thoroughly and will oversee the research in its entirety. I hereby acknowledge my role as the ***principal investigator of record****.*

Faculty Sponsor:

____

(typed/printed name) (signature) (date)

PLEASE COMPLETE AND E-MAIL TO: **irb-coordinator@ncsu.edu**
Please include consent forms and other study documents with your application and submit as one document. *Electronic submissions to the IRB are considered signed via an electronic signature. For student submissions this means that the faculty sponsor has reviewed the proposal prior to it being submitted and is copied on the submission.

****

For SPARCS office use only
Reviewer Decision (Expedited or Exempt Review)
☐ Exempt ☐ Approved ☐ Approved pending modifications
☐ Table

North Carolina State University
Institutional Review Board for the Use of Human Subjects in Research
GUIDELINES FOR A PROPOSAL NARRATIVE

In your narrative, address each of the topics outlined below. Every application for IRB review must contain a proposal narrative, and failure to follow these directions will result in delays in reviewing/processing the protocol.

A. INTRODUCTION

Briefly describe in lay language the purpose of the proposed research and why it is important.

The purpose of this study is to document the learning experiences and perceptions of science teachers' regarding a blended-learning professional development

If student research, indicate whether for a course, thesis, dissertation, or independent research.

n/a

B. SUBJECT POPULATION

How many subjects will be involved in the research?

N=15

Describe how subjects will be recruited. Please provide the IRB with any recruitment materials that will be used.

Participants will be recruited from a sample of 57 middle and high school teachers who participated in the Photonics Leaders II optics and photonics teacher professional development program.

List specific eligibility requirements for subjects (or describe screening procedures), including those criteria that would exclude otherwise acceptable subjects.

An email will sent to past participants in the program requesting participation

in a interview to collect information about the program.

Explain any sampling procedure that might exclude specific populations.

A maximum variation sampling strategy will be used to select information-rich participants and strengthen the research study design. This technique will be used to ensure the inclusion of a wide range of cases to strengthen the study's credibility.

The standard below will be used to select the middle and high school teacher participants:

4) They must have participated in PBLTPD
1) They must have completed a classroom implementation plan
2) They must meet one of the following implementation levels:
    a. **Level 1:** Completed the face-to-face training, used strategies with students in their classroom, and participated in the online follow-up component;
    b. **Level 2:** Completed the face-to-face training and online follow-up component but **did not** use strategies in their classroom;
    c. **Level 3:** Completed the face-to-face training and used strategies with the students in their classroom, but **did not** participate in the online follow-up component

PBLTPD face-to-face and implementation component, but not the online component

Disclose any relationship between researcher and subjects - such as, teacher/student; employer/employee.

The researcher is the manager of photonics blended learning professional development and have interacted have interacted with teacher participants during their participation in the program or supervisor in hired positions.

Check any vulnerable populations included in study:

☐ minors (under age 18) - if so, have you included a line on the consent form for the parent/guardian signature
☐ fetuses
☐ pregnant women
☐ persons with mental, psychiatric or emotional disabilities
☐ persons with physical disabilities
☐ economically or educationally disadvantaged
☐ prisoners
☐ elderly
☐ students from a class taught by principal investigator

☐ other vulnerable population.

7. If any of the above are used, state the necessity for doing so. Please indicate the approximate age range of the minors to be involved.

N/A

C. PROCEDURES TO BE FOLLOWED

In lay language, describe completely all procedures to be followed during the course of the experimentation. Provide sufficient detail so that the Committee is able to assess potential risks to human subjects. In order for the IRB to completely understand the experience of the subjects in your project, please provide a detailed outline of everything subjects will experience as a result of participating in your project. Please be specific and include information on all aspects of the research, through subject recruitment and ending when the subject's role in the project is complete. All descriptions should include the informed consent process, interactions between the subjects and the researcher, and any tasks, tests, etc. that involve subjects. If the project involves more than one group of subjects (e.g. teachers and students, employees and supervisors), please make sure to provide descriptions for each subject group.

Participants will participate in interviews for one hour and discuss their experience in the hybrid professional development program. They will answer a short demographic interview preceding the interview.

How much time will be required of each subject?

One hour

D. POTENTIAL RISKS

State the potential risks (physical, psychological, financial, social, legal or other) connected with the proposed procedures and explain the steps taken to minimize these risks.

I will assign you a fictitious name and take every precaution to ensure that your identity is not identifiable. There is a slight possibility that someone may read this dissertation and may be able to identify you in this research.

2. Will there be a request for information that subjects might consider to be personal or sensitive (e.g. private behavior, economic status, sexual issues, religious beliefs, or other matters that if made public might impair their self-esteem or reputation or could reasonably place the subjects at risk of criminal or civil liability)?

No

If yes, please describe and explain the steps taken to minimize these risks.

Could any of the study procedures produce stress or anxiety, or be considered offensive, threatening, or degrading? If yes, please describe why they are important and what arrangements have been made for handling an emotional reaction from the subject.

> No

How will data be recorded and stored?

> Data from interviews will be transcribed into digital documents saved on the computer and in backed up on an external drive. All field notes will be transferred to detail format and archived in PBLTPD study. Archrival documents will be stored in PBLTPD folder and backed up on an external drive.

How will identifiers be used in study notes and other materials?

> I will assign you a fictitious name and take every precaution to ensure that your identity is not identifiable and participants will grouped within a cohort based on the time of participation.

How will reports will be written, in aggregate terms, or will individual responses be described?

> Report will be using cohort designation for aggregate information and fictitious names for individual responses.

If audio or videotaping is done how will the tapes be stored and how/when will the tapes be destroyed at the conclusion of the study.

> Interviews will be digitally recorded, saved on the computer and backed up on an external drive.

Is there any deception of the human subjects involved in this study? If yes, please describe why it is necessary and describe the debriefing procedures that have been arranged.

> No

E. POTENTIAL BENEFITS

This does not include any form of compensation for participation.

What, if any, direct benefit is to be gained by the subject? If no direct benefit is expected, but indirect benefit may be expected (knowledge may be gained that could help others), please explain.

> There are no known benefits to you for participating in this study. However, the information gained from this study could be used to improve the delivery of professional development and support teachers in their ongoing professional learning endeavors.

COMPENSATION

Please keep in mind that the logistics of providing compensation to your subjects (e.g., if your business office requires names of subjects who received compensation) may compromise anonymity or complicate confidentiality protections. If, while arranging for subject compensation, you must make changes to the anonymity or confidentiality provisions for your research, you must contact the IRB office prior to implementing those changes.

Explain compensation provisions if the subject withdraws prior to completion of the study.

No compensation will be provided to participants.

If class credit will be given, list the amount and alternative ways to earn the same amount of credit.

COLLABORATORS

1. If you anticipate that additional investigators (other than those named on **Cover Page**) may be involved in this research, list them here indicating their institution, department and phone number.

N/A

Will anyone besides the PI or the research team have access to the data (including completed surveys) from the moment they are collected until they are destroyed.

N/A

H. CONFLICT OF INTEREST

1. Do you have a significant financial interest or other conflict of interest in the sponsor of this project? *NO*

2. Does your current conflicts of interest management plan include this relationship and is it being properly followed? _____

I. ADDITIONAL INFORMATION

If a questionnaire, survey or interview instrument is to be used, attach a copy to this proposal.
Attach a copy of the informed consent form to this proposal.
Please provide any additional materials that may aid the IRB in making its decision.

J. HUMAN SUBJECT ETHICS TRAINING

*Please consider taking the Collaborative Institutional Training Initiative (CITI), a free, comprehensive ethics training program for researchers conducting research with human subjects. Just click on the underlined link.

APPENDIX B: Informed Consent

North Carolina State University

INFORMED CONSENT FORM for RESEARCH

Title of Study: Science Teachers Experiences Adopting Innovations in a Blended Learning Photonics Professional Development

Principal Investigator: Pamela O. Gilchrist Faculty Sponsor: Tamara V. Young

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What are some general things you should know about research studies?

You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of research studies is to gain a better understanding of a certain topic or issue. You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above.

What is the purpose of this study?

The purpose of this study is to document the learning experiences and perceptions of science teachers' regarding a blended-learning professional development. The study will examine to what extent does teachers' experiences and perceptions influence their classroom implementation of learned materials and strategies, post intervention.

What will happen if you take part in the study?

If you agree to participate in this study, your total time commitment would be approximately one hour. The first hour would require you to complete a short demographic survey and the remaining time will consist of a semi-structured interview to discuss your learning experiences in the blended- learning professional development. The semi-structured interview will occur at your school, via phone, or at a agreed upon convenient location

Risks

Although the researcher will assign you a fictitious name and take every precaution to ensure that your identity is not identifiable. There is a slight possibility that someone may read this dissertation and may be able to identify you in this research.

Benefits

There are no known benefits to you for participating in this study. However, the information gained from this study could be used to improve the delivery of professional development and support teachers in their ongoing professional learning endeavors.

Confidentiality

The information in the study records will be kept confidential to the full extent allowed by law. Data will be stored securely in state measures taken to protect the security of data. No reference will be made in oral or written reports, which could link you to the study. You will be given an unique identifier and all information will be analyzed internally and your anonymity protected.

Compensation

You will not receive anything for participating in this study.

What if you have questions about this study?

If you have questions at any time about the study or the procedures, you may contact the researcher, Pamela Gilchrist at pogilchr@ncsu.edu, or 919.515.5570.

What if you have questions about your rights as a research participant?

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant
in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (919/515-4514).

Consent To Participate

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled."

Subject's signature______________________________ Date _________________
Investigator's signature__________________________________

APPENDIX C: Email Letter

Title of Project: Science Teachers Experience Adopting Innovations in a Photonics Blended Learning Teacher Professional Development

March 20, 2013

Dear Teacher,

I am the doctoral student in Leadership, Policy, Adult and Higher Education program at North Carolina State University. This purpose of this letter to request your participation in my doctoral research study. My research goal is to understand teachers' experiences in a blended professional development program post intervention. I am keenly interested in learning the needs of teachers regarding implementation of innovations.

For the study, I am recruiting middle and high school science teachers who are past participants of the Optics and Photonics Teachers professional development program offered during the during the following three years: 2009, 2010, 2011. You are being asked to participate in one face-to-face interview at a mutually agreed upon location. Each interview will take approximately one hour and will consist of a series of open-ended questions.

It is expected that these interviews will take place during the first week of April and end the first week of May 2013. If you are available and interested in participating in this endeavor, please contact me via email at xxxxxxx or by phone at xxxxxx at your earliest convenience or no later than March 31, 2013.

I greatly appreciate your time and consideration of this request. I feel this research will be of great to education of science teachers. I look forward to hearing from you.

Kind Regards,

APPENDIX D: Demographic Survey

Title of Project: Science Teachers Experience Adopting Innovations in a Photonics Blended Learning Teacher Professional Development

Time and Location:

Pseudonym:
Current Position Title: ____
Current Teaching Appointment: _____Middle _____High
Subject Area: ____
Gender: ____
Ethnicity: ____
Year of Participation in Optics and Photonics Program: _____2009 ____2010 ____2011
Type of School: _____Rural ____Urban ____Magnet ____Private _____Charter
_____Other

8. What strategies do you use to engage students in learning science? (check all that apply)

- o Lecture
- o Individual work assignments
- o Small group work assignments
- o Hands-on labs
- o Problem-based learning
- o Science visuals and simulations (multi-media)
- o Scientific method
- o Demonstrations

9. How long have you been teaching science?

10. Where do you currently teach? (i.e., county, school name and district)

APPENDIX E: Interview Protocol

Title of Project: Science Teachers Experience Adopting Innovations in a Photonics Blended Learning Teacher Professional Development

Time and Location:

Pseudonym:

Introductory Statement:
Thank you for agreeing to participate in the study. Before we begin the interview, please take a few minutes to complete the demographic survey. Today, we will discuss your experiences in the Photonics Blended Learning Teacher Professional Development workshop. This interview will take about 1 hour of your time. I would like to focus specifically on your experiences during and after your workshop experience.

Interview Questions:
PBLTPD Experience and Factors Impacting Implementation
1. Why did you decide to participate in the photonics blended-learning professional development?
2. What did you learn from your participation in PBLTPD workshop?
3. How did PBLTPD workshop compare to your other workshop formats in your school district?
   PROBE: format, resources, approach, use of Moodle or Elluminate
4. How have you use it?
   a. If not, why not?
5. What motivated your use of?
6. What deterred your use of?
   (Probe for school context, federal mandate, peers, media, status, learning style, professional goal)
7. What resources would help you in using the PBTPD strategies?
8. Describe your school context and aspects that influence your use of optics and photonics content?

9. What challenges did you experience in the blended learning professional development?
   PROBE for experience in face-to-face, and online part live sessions and using the learning management system
10. What other professional development have you taken that complements PBLTPD program?
11. How did you go beyond the workshop experience to learn more about optics and photonics content) Repeat question and include inquiry/constructivist strategies, Moodle and Elluminate?
11a. How did you go beyond the workshop experience to learn more about inquiry strategies?
11b. How did you go beyond the workshop experience to learn more about web-based tools?
12). What components of the workshop are you still using from the workshop? Explain
13). What difficulty did you experience in the workshop with content, activity or people?

Now let's discuss what you learned and used from PBLTPD

Implementation of PBLTPD Content, Web-based technology and
14. What did you implement in your classroom after the workshop?

Content
14a) What did you do with the photonics content learned from the program into your classroom?
If they have not implemented resources ask why not.
14b) In what way have you used this information in different settings?
(Share examples of use or nonuse?)
14c) How have you modified the content for different purposes? Explain why?

Inquiry/Constructivist Approaches
15a) What did you do with the Inquiry/Constructivist Approaches learned from the program into your classroom?
If they have not implemented resources ask why not.
15b) In what way have you used this information in different settings?
(Share examples of use or nonuse?)
15c) How have you modified the inquiry/constructivists approaches for different purposes? Explain why?

Web-Based Technology (Moodle, Elluminate, Wiki, Forum)
16a) What did you do with the Inquiry/Constructivist Approaches learned from the program into your classroom?
If they have not implemented resources ask why not.
17b) In what way have you used this information in different settings?
(Share examples of use or nonuse?)
17c) How have you modified the web-based tools for different purposes? Explain why?

Closing Questions:

18. If you had a magic wand with all the resources and all time to design a blended learning professional development, what would you do? Explain

19. Is there anything else you would like to share?

APPENDIX F: Participant Field Notes

Title of Study: Science Teachers Experience Adopting Innovations in a Photonics Blended Learning Teacher Professional Development

DATE OF OBSERVATION:

1. APPEARANCE OF PARTICIPANTS (PHYSICAL CHARACTERISTICS, DISTINGUISHING CHARACTERISTICS, CLOTHING, APPROXIMATE AGE, GENDER)
2. VERBAL BEHAVIORS AND INTERACTIONS (TONE, RESPONSE TO QUESTIONS)
3. PHYSICAL BEHAVIORS AND GESTURES (NONVERBAL CUES, BODY MOVEMENTS, OVERALL PATTERNS WHEN RESPONDING, OUTCOME, COMFORT LEVEL)
4. PERSONAL SPACE
5. OTHER PERTINENT OBSERVATION/FIELD NOTES

APPENDIX G: Document Analysis Form

1. TYPE OF DOCUMENT:

2. UNIQUE PHYSICAL CHARACTERISTICS OF THE DOCUMENT:

3. DATE(S) OF DOCUMENTS:

4. AUTHOR (OR CREATOR) OF THE DOCUMENT:

POSITION (TITLE):

5. FOR WHAT AUDIENCE WAS THE DOCUMENT WRITTEN?

6. DOCUMENT INFORMATION (There are many possible ways to answer A-E)

A. List three things the author said that you think were important.

B. What do you think this document was written for?

C. What evidence in the document helps you know why it was written? Quote from the document.

D. List information about teachers' choices to integrate technology, pedagogy or content into their classroom, demographics data or any other relevant information pertaining to the study focus. Tally intended versus actual.

E. Write a question that is left unanswered by this document.

Modified from the National Archives and Records Administration, Washington, DC 20408

APPENDIX H: Archival Documents

Workshop Pre-Survey

1. Do you currently teach the concepts of optics and photonics to your students?

2. If you answered "Yes" to Question 1, what strategies do you use to teach optics and photonics?

3. If you answered "No" to Question 1, what resources and/or information do you need to be able to teach optics and photonics in your classroom?

4. What strategies do you use to engage students in learning science? (check all that apply)

   o Lecture
   o Individual work assignments
   o Small group work assignments
   o Hands-on labs
   o Problem-based learning
   o Science visuals and simulations (multi-media)
   o Scientific method
   o Demonstrations

5. How do you integrate current science trends into your instructional practices?

6. How do you promote science, technology, engineering, and mathematics (STEM) careers or real world applications of science to your students?

7. What experience do you have with online learning environments?

8. What grade level and subject do you teach?

9. Please share what you hope to gain from the Photonics workshop.

10. How long have you been teaching science?

11. Where do you currently teach? (i.e., county, school name and district)

12. What would permit or impede your full commitment in completing the year-round program experience?

Inquiry and Content Reflection

1. How could you use the photonics inquiry activities in your classroom? (If not, please tell why?)

2. What specific strands and/or standards do these activities align with in the standard course of study?

3. How would you use these activities to promote optics and photonics?

4. Which avenue do you plan to share these activities: a) in your classroom, b) with your colleagues or c) in the Photonics Leaders II Program? (Explain how in one or more)

5. How will you connect these optics and photonics activities with current events, careers, and college preparation for students?

Archival Documents
Internship Reflection

1. What did you find most useful in the laboratory and industry tours?

2. What would you like to know more about as a result of the tours?

3. What else would you like to see in the optics and photonics arena?

4. How do you plan to integrate these activities: a) in your classroom, b) with your colleagues or c) in the Photonics Leaders II Program? (Explain how in one or more)

Archival Documents
Technology Reflection

1. How do you use technology to engage learners in your classroom instruction?

2. Which strategies have you discovered work well with students to delve deeper (enrich learning) into the content?

3. How have you used visualizations to demonstrate abstract concepts to support or extend your students conceptual understanding of science concepts? (Please share best practices you have used in your classroom)

4. Which of the following technologies have you used with your students:
   _____ Blackboard,
   _____ Elluminate Live
   _____ Wikis or Blogs
   _____ Wimba
   _____ DIMDIM
   _____ Any other technology
   If not, which one would you like to learn more about?

5. How do you plan to integrate Elluminate and/or Physlets: a) in your classroom, b) with your colleagues or c) in the Photonics Leaders II Program? (Explain how in one or more)

Archival Documents
Implementation Plan Document

Teachers:
Please use this form to outline your plans to implement one or more of the Photonics activities and concepts that you have been introduced to in this workshop. We suggest that you use one sheet for each new Photonics activity, lesson, or concept that you are going to integrate into your curriculum. We will use these sheets in our follow-up meetings to see how you plans have progressed. Feel free to modify this form later to best meet your needs.

Implementation Plan for:		**Class:**	**Teacher:**	**School:**
Actions:	**Dependencies:**	**Timeline:**	**Resources:**	**Evaluation:**

Implementation Question Reflection

Name: School:

1. What activity did you present, with whom, how many, and how was it presented (use descriptive data and include your lesson plans and student activity sheets)?

2. Please describe how the teacher workshop resources were introduced in your class, school, workshop or pre-college program. (For example what strategy did you use to introduce the resources as an inquiry activity, a demonstration, stations, lecture, project or simulation) How much time was allocated? What resources did the students have available to them? Did the students work in teams? How did you structure the student activities? What did the students learn in regards to Optics and Photonics?

3. What did the students or teachers learn from your presentation or lesson. Were they more engaged in the learning process? Was the experience informative about science technology, engineering and mathematics (STEM) careers?

4. What recommendations (if any) can you make to help us improve the Optics and Photonics professional development activity?

5. If you were given $350 materials grant to promote laser safety, optics and technology in your school or community, what materials would you purchase and what activities or competitions would you introduce to your students.

APPENDIX I: A Priori Code

Roger's Diffusion Theory Attributes of Innovation and Adopters Codes

Innovation Attribute	**Code Description**
Relative advantage	Economic factors, social status, expected benefits
Capability	Need, value, and belief
Complexity	Difficult or easy to use
Trialability	Time to experiment
Observability	Application in social system

APPENDIX J: Interview Confirmation

Dear Mr./Ms. XXXX,

Thank you for agreeing to participate in the Photonics Blended Learning research study on **Thursday**, **June 6th at 12:30 pm.**

Below is a link to the Informed Consent Form for this study, please click on the link (http://ncsu.qualtrics.com//SE/?SID=SV_a8GZMnrj7dWlRQh), read the document, select yes, type in your first and last name, today's date and submit the document to confirm your consent to participate in this research study.

Before the semi-structured interview, I ask you to complete the short demographic survey at the following link: http://ncsu.qualtrics.com//SE/?SID=SV_bOVZG6XSWqORxbL. Please leave the pseudonym space blank.

I will need you to call me fifteen minutes prior to your 8:30 am interview time at XXXXXXX. I will review the Informed Consent Form with you and proceed into the one-hour interview regarding your experiences in the teacher professional development program. The interview will be recorded and transcribed at a later date. We will not used Blackboard Collaborate due to unforeseen issues.

Please confirm receipt of this email and let me know if there are any problems with submitting your reply on the online documents. You may reach at XXXXXXXX, in case of an emergency.

Sincerely,

XXX

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