EXAMINING THE INFLUENCE OF PHYSICS FOCUSED PROFESSIONAL DEVELOPMENT ON ADVANCED PLACEMENT PHYSICS TEACHERS

by

JUSTINA A. OGODO

DENNIS W. SUNAL, COMMITTEE CHAIR

JAMES W. HARRELL, JR.
MICHAEL LAWSON
CRAIG SHWERY
CYNTHIA S. SUNAL

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ABSTRACT

There is a critical need to improve the pedagogical content knowledge of in-service physics teachers because of the large population of under-qualified teachers in the physics classroom. The need is even greater for the advanced placement (AP) physics teacher because of the level of rigor involved in the AP curriculum. This case study examined how participating in additional physics focused professional development influenced the instructional practice of AP physics teachers in a southeastern state of the United States. Fourteen AP teachers who received College Board training were purposefully selected from high schools in the state. From this population, seven teachers who experienced additional physics-focused professional development beyond the College Board training (APD) were compared with the other seven teachers with little or no additional in-service physics focused training (NAPD). The analysis of the quantitative data from the classroom observation indicated that there was a large treatment effect difference between the APD teachers and the NAPD teachers. The qualitative data from teacher interviews, surveys, and questionnaires was thematically analyzed and the result indicated that the APD teachers increased their PCK level after the intervention. In addition, the study found that although contextual factors influenced the type of instruction used by the teachers, these factors were more teacher-based than context-based. Due to the small sample population, the findings from this study represents initial empirical evidence of the influence of the intervention on the instructional practice of the AP physics teachers.

DEDICATION

This project and my entire educational pursuit is dedicated to the memory of my late father, Chief Christopher Odinde Ajeh. Papa, I miss you. Even in death, I can still feel your gentle spirit urging me on. Every milestone I have achieved was propelled by the solid foundation you gave me. You taught me to aim for the skies in a male dominated culture. I owe this to you. Rest in perfect peace in the bosom of the Lord. And to my mom, Madam Helen Ndogo Ajeh, who recently passed on while I was at the verge of completing this program, thank you for your endless prayers, support, and understanding as I pursued. Your worth cannot be quantified. Thank you for instilling in me and your grandchildren a positive outlook at life. Rest in perfect peace in the bosom of the Almighty.

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CHAPTER I:

INTRODUCTION

Advancing science education in the 21st century requires effective, continuous, and dynamic training of teachers in order to enhance and refine their classroom practices (Hodapp, Hehn, & Hein, 2009). The need to advance science education in schools has been a growing concern in the United States for over a century (National Research Council [NRC], 2006; National Commission on Teaching and America's Future [NCTAF], 2003). Research and other self-reports have indicated that U.S. students continue to lag behind their peers in other developed countries in science, technology, engineering, and mathematics (STEM) education (Gonzalez & Kuenzi, 2012; NRC, 2006; NSF, 2006; Program for International Student Assessment [PISA], 2012; Rogers-Chapman, 2014; TIMSS, 2012). The Trend in International Mathematics and Science Study (TIMSS, 2012) report has shown that, although the U.S. average scores in science for fourth and eighth grade students were above average on the TIMSS scale, these same students were ranked 20th in science education compared with other nations. In addition, there has been no significant change or measurable difference in science performance over the recent period of four years between 2007 and 2011 (National Center for Educational Statistics [NCES], 2015; PISA, 2012). Our schools continue to trail other developed countries and in some cases, developing countries, in STEM education (Obama, 2009). The percentage of U.S. students enrolling in STEM fields or pursuing STEM careers is lower than in many nations (Rogers-Chapman, 2012) and more U.S. students are ranked lower in physics education compared to their peers internationally (Carnevale, Smith, & Melton, 2011; Kuenzi, 2008; Meltzer, Plisch & Vokos, 2012; PISA, 2012; TIMSS, 2012).

Research has also indicated that one reason why students in the United States continue to under-perform in science in relation to their international peers is because many U.S. science teachers are not adequately prepared to deal with the current and future needs of students (Fisch & McCloud, 2012; Meltzer et al., 2012). This lack of adequate teacher preparation has resulted in producing students who are ill-prepared to compete globally in the 21st century for current jobs and for "jobs that don't even exist yet, using technologies that haven't been invented, or to solve problems we don't even know are problems yet" (Fisch & McCloud, 2012, 0.57).

These reports have shown that there is a strong need to aid science teachers in becoming effective in teaching science (Barlow, Frick, Barker, & Phelps, 2014). The National Commission on Mathematics and Science Teaching for the 21st Century (NCMST, 2000) noted "the most direct route to improving mathematics and science achievement for all students is better mathematics and science teaching" (p .7). Effective science teaching can be developed through continuous professional development training that provides support in how science is taught and, in turn, improves student achievement in science (Blank, de las Alas, & Smith, 2008).

Physics Education in the United States of America

Reform efforts at changing physics education in America have a very long history. Otero and Meltzer (2015) believe that "for almost as long as physics has been part of the high school curriculum, physicists have sought to change the way it's taught" (p. 51), but despite all reform efforts, there are growing concerns on the state of physics education across the United States because of the shortage of highly qualified secondary physics teachers (American Institute of

Physics [AIP], 2014; Banilower, Smith, Weiss, Malzahn, & Campbell, 2013). Physics is still taught mostly as lecture and uses a traditional approach that is very textbook-based and has been shown to be teacher-centered and ineffective (DeBoer, 1991; Heras, 2017; Tsai, 2002; Weinberg, 2003). Research on the state of physics education has indicated that although enrollment in high school physics has increased at an annual compounded growth rate of 5.1% between 1997 and 2013, the growth has not been matched by qualified physics teachers and that of the 1.38 million students enrolled in physics. The number of students taking Physics II and AP Physics grew much more quickly when compared to regular physics over the same period (Banilower, 2013; White & Tesfaye, 2014). Meltzer and Otero (2015) believe this growth in physics has been driven by the popularity of conceptual physics, AP physics, and high school graduation requirements. This creates a challenge in that schools must provide courses that are led by qualified physics teachers.

Universities in the United States are not graduating adequate numbers of physics teachers to meet the growing demands of high schools in the nation and the main reason is that very few, if any, university programs are currently designed to specifically prepare physics teachers (Wenning, 2011). As a result, more than ever before, many students are taking physics from teachers who were not specifically prepared to teach physics (White & Tesfaye, 2014). This is problematic because physics students in the United States must be prepared with quality physics instruction to meet the demands of the 21st century in regards to physics education if they are to compete comparatively with students from other countries as well as for the students to do better in physics on tests that compare them to international students.

Teacher Professional Development

Teacher professional development plays a central role in science reform education. For reform to take place in the classroom, it is important to teach teachers well in order for them to reach the students. A reformed-oriented classroom depends on teacher quality in subject matter knowledge, knowledge of how students develop and of how they learn, knowledge of pedagogy, knowledge of school context, and knowledge of pedagogical content knowledge and so forth. The current policy on science education is focused on improving teacher quality, teaching practices, and student learning outcomes (NCATE, 2009; *No Child Left Behind* [NCLB] Act, 2001; NRC, 1996; NSF, 1996; Shulman, 1986, 1987). The National Research Council (1996) believes a continuous training is needed for teachers from pre-service years to the end of their professional careers, in order to encourage the growth and sustained quality of teaching. Participating in continuous professional development is one of the mandates in the *NCLB* (2001) which aims at keeping teachers informed, grounded, and abreast with the changes in science education.

Professional development for in-service teachers in the form of institutes, workshops, seminars, and conferences is used as avenues to improve teacher instructional practice and to equip them with methods and strategies that help grow their pedagogical content knowledge (Abell et al. 2009; Loughran, Berry, & Mulhall, 2006; Okonlawon, 2010; Shulman 1986, 1987). Pedagogical content knowledge (PCK) is the blending of teacher content knowledge and pedagogical knowledge to enhance the teaching process (Kleickmann et al., 2013, Shulman, 1986, 87). Borko (2009) stated that professional development training helps teachers "enhance their knowledge and develop new instructional practices" (p. 3). Professional development provides "substantially more resources into preparing highly qualified science teachers for those students" (Meltzer et al., 2013, p. 8). According to research, teachers who receive over 100 hours of professional development demonstrate consistent positive effects on their instruction and "teacher training and expertise have been found to have a significant effect on the quality of teachers' practices" (Paek, Ponte, Sigel, Braun, & Powers; 2005, p. 2). Desimone (2011) believes teachers who participate in professional development activities with core features that emphasize content knowledge, active learning, coherence, collective participation and is continuous are more likely to experience changes and enhanced knowledge and skills in teaching. The ultimate goal of professional development is to improve teachers' PCK. Enhanced PCK produces effective pedagogical practices that leads to student achievement (Abell et al. 2009; Loughran, Berry, & Mulhall, 2006; Okonlawon, 2010: Rock, Courtney, & Handwerk, 2009).

The Advanced Placement Program

The Advanced Placement (AP) program was established by the College Board as a preparatory curriculum for high school students to enable them to prepare for college level coursework. The College Board is an American private, non-profit organization, formed as the College Entrance Examination Board (CEEB) with the aim of expanding access to higher education in the country. It provides a platform for students to be more competitive for college admission. Enrollment in advanced placement subjects has been growing and high school physics is not an exception. The growth in high school physics has spurred a renewed call for adequate teacher preparation because teachers play a vital role in influencing students' participation in the advanced placement program. Unfortunately, due to the severe shortage of well-prepared physics teachers, most AP physics classrooms are filled with teachers whose professional training and experiences are not in physics or physics education, and therefore, are lacking in the required academic qualifications to teach the subject effectively (Meltzer et al., 2011; Paek et. al. 2005). Because in-service teachers often receive training through professional development, the College Board provides a five-day summer professional development training for all AP content areas and teachers are strongly recommended to participate (College Board, 2012b).

The five-day training aims at developing teachers to learn “specific pedagogical techniques and content-specific strategies that can be incorporated in the classroom” and is focused on strategies of passing the AP examination (College Board, 2015-16, p. 3). Additional one- or two-day workshops are provided during the academic year. The College Board also provides resources and content-specific schedules/pacing charts during these trainings to guide teachers through the school year.

The APEX Professional Development Model

The Alliance for Physics Excellence (APEX) is a statewide project, funded by the National Science Foundation (NSF) as a part of the Mathematics and Science Partnership Program (Sunal et al., 2014). The APEX program aims at transforming physics education in a particular southeastern state in the United States of America by enabling pre-service and in-service physics teachers to acquire a deeper content knowledge of physics, and to employ effective pedagogical strategies in their classrooms. The professional development model provides a three-year continuous training that includes a two-week intensive summer training session and three additional two-day weekend workshops throughout each academic year. The training provides physics-focused professional development that is not commonly available to teachers by addressing critical variables of physics teacher preparation, teaching performance, and by exploring how these variables impact students. The strategies used in the training program are research based and have been shown to be effective toward improving physics knowledge and enabling students to experience higher achievement in physics education. Participants in the program include pre-service teachers and in-service teachers drawn from public high schools in the rural, urban, and suburban areas of the state.

Pedagogical Content Knowledge (PCK)

The concept of pedagogical content knowledge (PCK) was introduced by Shulman (1986) as the blending of teacher content knowledge and pedagogical knowledge. Shulman (1987) stated that teacher training programs improve teacher quality if they integrate content knowledge, knowledge of teaching and learning, and an enhanced level of pedagogical content knowledge. PCK, he noted, creates meaningful learning outcomes for students. While it is necessary to know science content, Abell, Park, Hanuscin, Lee, and Gagnon (2009) noted that knowledge on its own is not a sufficient condition for teaching because “science teachers must also have specific discipline focused knowledge about science learners, curriculum, instructional strategies, and assessment through which they transform their science knowledge into effective physics teaching and learning” (p. 79). The National Council for Accreditation of Teacher Education (NCATE, 2009) has stated that the current guidelines for pre-service teacher preparation hinges on teacher discipline content knowledge (DCK) of the subject to be taught and the PCK skills needed to achieve this knowledge. Professional development, when focused on DCK and PCK, equips teachers to combine content knowledge and pedagogical knowledge with classroom practices and skills, which together enable teachers to acquire the knowledge base that makes physics teaching more effective (Abell et al. 2009; Loughran, Mulhall, & Berry, 2006; Shulman 1986, 1987; Van Driel et al, 2001). Physics-focused professional development provides the physics teacher the access to acquire the teacher professional knowledge base needed to be effective in the classroom.

Statement of the Problem

Teachers are expected to be highly-qualified in the content they teach (NCLB, 2001). Compared to other science subjects, such as biology and chemistry, fewer numbers of physics teachers are adequately trained to meet the growing demands of student enrollment in America’s physics classrooms (Meltzer et al., 2012; NCES, 2014; White & Tesfaye, 2014). Many of the available teachers are inadequately prepared and are teaching outside the content areas they were certified to teach (Meltzer et al., 2013). As a result, students are often denied quality education (Banilower, 2013; National Center for Education Statistics [NCES], 2013; Sunal & Wright, 2016; White & Tyler, 2012). For example, in one southeastern state of the United States of America, over 90% of the physics teachers have undergraduate degrees in other science subjects. Most of these “physics” teachers are certified to teach biology; hence, less than 10% of the teachers are academically equipped to teach the subject. The growing need in the physics classroom calls for a content-focused professional development that targets this specific groups of teachers to ensure students’ learning needs are met (Desimone, Smith, & Ueno, 2006).

The increased enrollment in high school physics means more students are taking physics from teachers who are ill-prepared (Meltzer et al., 2012; NCES, 2014; White & Tesfaye, 2014). Although the college preparatory AP curriculum provides a deeper physics content knowledge and impacts students’ interest and persistence in STEM education, there is paucity of empirical studies on the effect of content-focused professional development on AP physics teachers (Sadler, Sonnert, Hazari, & Tai, 2014; Vilorio, 2014). This study examined the influence of physics focused professional development on AP physics teachers.

Purpose of the Study

Students' learning and achievement in any subject is inextricably tied to the quality and effectiveness of the teacher. This study examined the influence of physics-focused professional development on AP physics teachers. Advancing physics education depends on providing adequate training to improve the quality, performance, and effectiveness of the teacher, and equipping them to ensure students' learning needs are met. The aim of this study was to use an embedded case study design to explore the research questions and to offer initial findings that may lead to further research and to also add to current literature on content-focused professional development by examining how participating in a physics focused professional development influenced the instructional practice of AP physics teachers.

Research Questions

In order to teach advanced placement (AP) courses in high school, teachers are mandated by the College Board to participate in the content-focused professional development for the subject they teach. This study examined the influence of participating in additional physics-focused professional development on in-service AP physics teachers. It compared the instructional practice of teachers who experienced additional physics focused professional development with teachers who experienced little or no additional physics focused professional development beyond the College Board training.

The overarching question of this study was what are the effects of enhanced in-service physics focused professional development on advanced placement physics teachers' instructional practice? The study was guided by the following questions:

1. How does the level of reform-oriented instruction compare in classrooms of advanced placement physics teachers who experienced in-service physics focused

professional development and those teachers with little or no additional in-service physics focused professional development experiences;

2. How does participating in the physics focused professional development training affect advanced placement physics teachers' pedagogical content knowledge; and
3. What classroom and school context factors support or impede (mediate) effective implementation of reformed-oriented teaching in AP physics classrooms?

Rationale and Significance of the Study

The literature reports that 27% of students attend schools with no offered physics courses. Only about 9% of physics teachers in the southeastern state where this study took place are physics majors compared to 37% nationally (NCES, 2014; Meltzer et al., 2012; Sunal et al., 2016; White & Tesfaye, 2014). About a third of physics teachers in America's classroom have not taken a course for college credit in either science or the teaching of science in the last ten years (Banilower, 2013). Teachers who are inadequately prepared tend to continue to use traditional teacher-centered approaches in teaching despite reform efforts on science education. Inadequate preparation and lack of content knowledge have been cited for teachers' failure or inability to use reform-based teaching in the classroom (Sunal, Sunal, & Wright, 2006). The unfavorable experiences of students and loss of interest in learning science is often traced to inadequate teacher preparation, and lack of effective pedagogy (Duncan, 2010; Guskey, 2002; Park, Jang, Chen & Jung, 2010). Because teacher professional development is one of the most effective methods of providing intervention for improving teacher quality, what may be needed is a more intensive professional development model that involves multi-year continuous training that equips teachers to improve their content knowledge and use of reform-based teaching.

Conceptual Framework

This research was guided by the conceptual understanding that effective professional development is a necessary foundation for the implementation of standards-based reform in the science classrooms. The study examined the influence of physics focused professional development on advanced placement physics teachers through the lens of the *No Child Left Behind* (2001) guidelines on effective professional development, which are a) sustained, intensive, and classroom-focused; b) improve and increase teachers’ content knowledge; and c) increase teacher pedagogical skills by advancing their understanding of effective instructional strategies. It utilized Shulman’s (1986) concept of pedagogical content knowledge to examine how professional development enhances teachers’ knowledge base to produce meaningful learning for the students (NCLB, 2001; Shulman, 1986).

In addition, the study was guided by Desimone’s (2009) framework on effective professional development. This framework uses five core features (content focus, active learning, coherence, duration, and collective participation) to evaluate the effectiveness of professional development on the participants and subsequently on students’ learning. The framework also explains how contextual factors such as student characteristics, teacher characteristics, and school characteristics can influence the effectiveness of implementing the gains from professional development training. Studies have noted a relationship between these five core features with positive effects on teacher practice and student learning (Blank & Alas, 2008; Ingvarson et al., 2005; Jeanpierre, Oberhauser, & Freeman, 2005; Smith, Desimone, & Ueno, 2005; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007).

Overview of Research Design and Methodology

This study used an embedded case study to evaluate the influence of physics focused professional development on AP physics teachers. Case study is an "empirical inquiry that investigates a contemporary phenomenon in depth, is recommended when "how" and "why" questions are posed, when the investigator has little control over events within its real life context" (Yin, 2009, p. 1, 18). Case study allowed the researcher to use multiple sources of data to provide a robust and in-depth understanding of a case or phenomenon organized within some boundaries (Creswell, 2007; Denzin, 1978; Yin, 2009). Case study was also used to explain presumed causal links and to describe interventions as they occur in real life contexts.

Fourteen AP physics teachers were purposefully selected from a population of teachers currently teaching at least one AP physics course in high schools in a southeastern state. All the teachers have experienced the College Board professional development workshop for AP physics teachers. They have also participated in the state Mathematics and Science Teaching initiative program and the state Science in Motion programs. The Science in Motion program is the State of Education funded partnership between universities and high schools with the goal of providing high-tech laboratory experiences for students and effective professional development for teachers. Each Science in Motion site provide resources to area high schools and opportunity for teachers to network with peers, and share both content knowledge and teaching techniques.

Participation was open to both genders and all ethnic groups, with teaching experience between two and 20 years. Of the fourteen teachers, seven teachers who experienced additional physics focused professional development from the APEX professional development were selected as the intervention group. The other seven teachers with little or no additional professional development experiences were selected from the pool of AP physics teachers in the state and they represented the comparison group.

Qualitative and quantitative data were collected concurrently from the reformed teaching and observation protocol (RTOP) for classroom observation, the Content Representation (CoRe) teacher interviews, Physics Teaching Efficacy and Beliefs Instrument (PTEBI) surveys, and the TIMSS AP physics teacher questionnaires. A Pedagogical and Professional Experience Repertoires (PaP-eRs) was generated from the CoRe and researcher/observer's field notes.

The classroom observations lasted between 50 - 84 minutes on two consecutive visits. The interviews were conducted after the second visit and lasted an average of 22 minutes. The RTOP data was quantitatively analyzed using descriptive and inferential statistics. Due to the small sample size, effect size was also calculated to determine the magnitude the effect of training had on participants' instructional practice. The quantitative data was used to respond to RQ1. The qualitative data from interviews, surveys, and questionnaires were thematically analyzed and used to respond to RQ 2 and RQ3.

This embedded case study design emphasized the quantitative data and used the qualitative data to inform and validate the quantitative data. The mixed data was integrated at the analysis and interpretation stage to seek convergence among the result (Tashakkori & Teddlie, 2010). The comparative analysis of the two groups provided insight for the study. The researcher acknowledges the difficulty experienced in having direct comparability and equivalence across measures between the participants. An attempt was made to pair up the comparison group with the intervention group on common criteria as much as possible.

Assumptions

The research was conducted on the assumptions that 1) participation in the study was voluntary; 2) all participants were teaching at least one AP 1 physics course at the time of the study; 3) the APD teachers were participants in the physics focused professional development training model; 4) the NAPD teachers were typical AP physics teachers from the state where the study was conducted, and that this group had little or no additional physics focused training beside the College Board and the state science in motion training; 5) the NAPD teachers will not improve their instructional practice in the absence of additional physics focused professional development teachers ; 6) the teachers were truthful in responding to the surveys, questionnaires, and interview protocol and they represented the classroom observed accurately and, 7i) the privacy and confidentiality of the participating teachers was protected during and after the study.

Limitations

Participation in the study was bounded around teachers who taught at least one AP physics course for the duration of the study. The sample size was limited by the number of AP physics teachers participating in the APEX program. The small sample size also limited effective matching of the teachers based on years of teaching experience. Because this study represents an initial empirical study on these subsets of physics teachers, it will limit the generalizability of the findings. Although the research attempted to ensure fair representation of both groups for meaningful comparison, there is no guarantee that the comparison groups were exactly equal in all aspects.

Definition of Terms

Advanced Placement curriculum: a preparatory college curriculum established by College Board to prepare and expand high school students for college level coursework.

Case study: an “empirical inquiry that investigates a contemporary phenomenon in depth, is recommended when “how” and “why” questions are posed, when the investigator has little control over events within its real life context.

Comparison group: participants who experienced little or no additional focused professional development.

Intervention group: participants who experienced additional physics focused professional development from the professional development model used for this study.

Content Knowledge (CK): the representation of a teacher’s understanding of the subject matter being taught.

Enhancer: any factor that promotes instructional activities used in the delivery of the content within a classroom setting.

Inhibitor: any factor that limits or hinders instructional activities used in the delivery of content within a classroom setting.

Pedagogical Content Knowledge (PCK): the blending of teacher content knowledge and pedagogical knowledge to enhance the teaching process (Kleickmann et al., 2013).

Professional development: workshops, institutes, courses, programs, and related activities that are designed presumably to provide teachers with new ideas, skills, and competencies necessary for improvement in the classroom.

Purposeful selection: choosing a desired number of individuals to participate in the study based on certain criteria.

Science reform teaching: a shift from the traditional teacher-centered, lecture-based method to a student-centered, activity-based learning process that involves the use of enhanced instructional practices to engage and provide conceptual learning for the students.

Random selection: the sampling technique where a group of participants were selected from a larger group (a population) based on those who responded to the invitation to participate.

Reformed teaching: teaching that incorporates the constructivist, inquiry-based methods in teaching science (MacIsaac & Falconer, 2002).

School context: factors within a school setting that can influence teaching and learning. This will include inner class context and outer class context.

Science in Motion: State of Education funded partnership between universities and high schools with the goal of providing high-tech laboratory experiences for students and effective professional development for teachers.

Self-efficacy beliefs: individuals' judgments of their competence to execute a particular task; "one's confidence in engaging in specific activities that contribute toward progress to one's goal" (Erlich & Russ-Eft, 2011, p. 5).

Teacher practices: instructional activities and pedagogical strategies used in the delivery of the content within a classroom setting.

Study Overview

This chapter provided an introduction and overview to the study; examining the influence of professional development on AP physics teachers. Chapter II will provide an in-depth review of literature that relates to this study. Chapter III will detail the method that will be used for the study. This will include discussions on the research design, data collection procedure, and discussion of the instruments used. Chapter IV and V will provide the results and discussion.

CHAPTER II:

REVIEW OF LITERATURE

This review of literature attempts to connect current research and reports relating to professional development and its impact on the teachers' pedagogical content knowledge. It examined if professional development training is producing the desired outcomes of reformed-oriented instruction. The review was organized as follows: 1) science education reform in America, 2) current state of science education, 3) current state of physics teaching, 4) research on professional development programs, 5) framework on effective professional development, 6) research on teacher PCK, 7) physics teaching and the school context, 8) theoretical models of research study, 9) instrumentation and, 10) chapter summary.

Science Education Reform in America

Since the progressive era science education reform has focused on the shift from teacher-centered to learner-centered approaches in education. Dewey (1938) introduced "learning science by doing," a process that provides practical experience and skills to promote students' conceptual learning. The teachers' role was to facilitate and inspire student desire for knowledge. But despite the move toward inquiry learning, the era witnessed a strong adherence to the textbook. Yager (2000) noted that students learned more from textbooks because "textbooks were conceived as a way of determining what teachers taught and included in the teaching approaches that would ensure that the reforms would succeed" (p. 51).

A second wave of science education reform was catalyzed by Russia's orbit with Sputnik in 1957. This act renewed the calls for improvement of science curriculum and teacher quality.

Teacher education came under scrutiny because of the “growing discrepancy between what science teachers knew and the science they needed to know to be effective teachers” (Kahle & Woodruff, 2011, p. 51). The focus on science curriculum reform continued in the mid-70s with the cognitive science approach becoming popular. There was a move from academic preparation of students for science careers to preparing all students to be successful in science and technology.

The early 1980s until the 1990s witnessed another era that was spurred by the publication of the National Commission on Excellence in Education (NCEE, 1983) *A Nation at Risk*. This was followed by other reports: the Carnegie Task Force report (1986); the NSTA’s *Scope, Sequence, and Coordination* (1989); the American Association for the Advancement of Science’s (AAAS) *Science for All Americans*: Project 2061; the Benchmarks for Scientific Literacy (1993); and the National Science Education Standards based on inquiry learning (NSES; NRC, 1996). These reports proposed change in teacher education that reflects teacher quality, subject matter preparation, and instructional approaches that support *teaching science as inquiry*. The NRC (1996) defined inquiry as a “process where students describe objects and events, ask questions, construct explanation, test those explanations against current scientific knowledge and their assumptions, use critical and logical thinking, and consider alternative explanations” (p. 2).

Science education reform was propelled by pedagogical content knowledge (PCK) (Shulman, 1986), which is the blending of content knowledge and pedagogical knowledge. Although it was not research-based at that time, it was assumed to prepare science teachers in making a difference in students’ achievement. PCK is viewed as the knowledge base for teacher preparation and for effective teaching. Lastly, *No Child Left Behind* (NCLB, 2001) added to the “policy aimed at improving science teachers and teaching” (Kahle & Woodruff, 2011, p. 51).

In addition to the theoretical knowledge from teacher education, there was a strong argument for clinical experience for pre-service teachers. Clinical practice, it was argued, would connect theory to practice. Darling-Hammond (2010) stated that "powerful teacher education programs should have a clinical curriculum as well as a didactic curriculum… no amount of coursework can, by itself, counteract the powerful experiential lessons that shape what teachers actually do" (p. 40, 43). All these reform efforts led to redesigning and transforming teacher education programs with the aim of producing quality teachers that could translate effective qualities into students' learning and achievement (Darling-Hammond, 2010).

Current State of Science Education

Based on the reform agenda, teachers were expected to possess the content knowledge to teach, and the pedagogical skills to improve students' learning. The National Science Education Standards (NSES [NRC], 2000) was released with key features placing the responsibility of implementing reform practices on the teachers: 1) the learner engages in scientifically oriented questions; 2) the learner gives priority to evidence in responding to questions; 3) the learner formulates explanations from evidence; 4) the learner connects explanations to scientific knowledge; and 5) the learner communicates and justifies explanations to enhance teachers' content knowledge and instructional practices. Some believe that the intent was to make teachers more successful at evaluating and using instructional materials and strategies to engage students (Kahle & Woodruff, 2011; MacKinnon et al., 2006), but the focus was that science education should involve the use of inquiry-based, student-centered instructional practices that facilitate students' conceptual knowledge (Abd-El-Khalich & Akerson, 2004; Akerson, 2005; NRC, 1996).

Despite all the reform efforts, little has changed concerning how science is taught in a majority of America's classrooms (Capps & Crawford, 2009; Kahle & Woodruff, 2011; Sunal & Wright, 2006). Although inquiry teaching was favored, it was not extensively implemented because teachers did not know how (Sunal & Wright, 2006). Capps and Crawford (2009) believe inadequate teacher preparation is linked to teacher unfamiliarity with inquiry instruction. Teacher unfamiliarity with inquiry is also cited as a major reason for non-implementation of inquiry which leads to structuring inquiry as "cookbook style laboratories" (DeBoer, 2004; Gabel, 2006; Sunal & Wright, 2006).

To examine how inquiry is enacted in precollege science classrooms in six countries, Abd-El-Khalick et al. (2004) used a comparative analysis from six symposium participants to shed light on inquiry as an instructional approach and as a learning outcome. They based their investigation on 1) the philosophical and practical conceptions of inquiry; 2) images of how inquiry was enacted; and 3) factors and conditions, internal and external to the educational setting, which facilitate or impede inquiry-based science education. Data was collected through observation of how inquiry was perceived and enacted in the classroom based on the curriculum, materials, instruction, and assessment practices. They used qualitative methods to synthesize the data and found that conceptions of inquiry and classroom enactment were highly contextualized, and that most science teachers have never directly experienced authentic scientific inquiry during their science education or within their teacher education programs; therefore, they were unable to enact or use inquiry in their classroom.

In another study to examine the extent to which teachers' views of inquiry and practice aligned with ideas in reform-based documents, Capps and Crawford (2012) used mixed methods to collect data from twenty-six 5th–9th-grade teachers selected across the country. The quantitative and qualitative data collected were analyzed based on the lesson descriptions, classroom observations, videotape data, questionnaires, and interviews to assess the teaching practice and views of inquiry and nature of science (NOS) of the teachers. They found that while inquiry was evident in some of the classes observed, the understanding of inquiry was conspicuously absent for all the participants. They noted that the lessons observed had “neither explicit nor implicit instruction related to understandings about inquiry” (Capps & Crawford, 2012, p. 510).

Using inquiry learning instruction moves the teacher’s role from being the center of knowledge in lecture-based instruction to being a guide and facilitator who uses collaborative groups to engage students in explaining, clarifying, and justifying what they have learned while the teacher listens and encourages broad participation, and uses the information to form the core of the classroom instruction (NSES, 1996). Because of the complex and sophisticated nature of inquiry, there is the need for a strong emphasis on significant professional development and continuous support of teachers (Capps & Crawford, 2009).

Reformed-based Teaching

Reformed-based teaching emphasizes students’ thinking and learning over lecture-based instruction. Teachers in a reformed-based classroom make decisions that are student-centered and not teacher-centered. Within such environment, a skilled teacher leads students to recognize the expertise that different members of the group add to the endeavor and the greater value of argument. Science teaching can be more effective, if it involves the use of reformed-oriented instruction because it creates conceptual understanding that promote student learning and achievement (Abell, 2004; Desimone, 2011; Loughran, Berry, & Mulhall, 2006; Okonlawon, 2010; NRC, 1996; NCLB, 2001).

Reformed-based science teaching is challenging for most teachers because they either have not experienced or seen it, or they do not have the subject-matter knowledge to carry out such instructional practices (Schwarz & Gwekwerere, 2007). The National Council for Accreditation of Teacher Education (NCATE, 2009) believes the call for change in teacher education programs is beginning to gain traction because the emphasis now, is more than content knowledge, but on understanding the methods of teaching, and acquiring clinical experiences from classrooms. It is also believed that there is increased use of different teaching strategies and inductive learning processes aimed at moving teaching and learning from rote memorization to learner's active participation.

The current reform effort, the Next Generation Science Standards (NGSS, 2013), is focused on improving science education, teacher professional development, assessments and accountability with an end result of student achievement. The NGSS is based on NRC (2012) *A Framework for K–12 Science Education* and the *Common Core State Standards Initiative.* These initiatives are grounded in the most current scientific evidence-based research. The NGSS framework interconnects a) practices, using specific scientific practice relevant to each concept; b) crosscutting concepts, "common themes in the Project 2061 Benchmarks," and c) core ideas, core science concepts such as scale, systems, and models. Bybee (2014) noted that NGSS "set a new stage for educational reforms at the national, state, and local levels" (p. 211) by providing the foundation for "concepts all K-12 students should know and the science and engineering practices they should be able to do" (p. 212).

Current State of Physics Teaching

Like other sciences, concern about the state of physics education lingers. The method of teaching physics remains largely unchanged in spite of the inductive method being favored over the years because of inadequate teacher preparation. DeBoer (1991) stated that physics has been taught mostly as lecture-type and is very textbook-based. Sunal and Wright (2006) noted that the inadequacy of ongoing staff development with follow-up monitoring are some reasons for teacher resistance to change. The publication of *America's lab report: Investigating high school science* (NRC, 2006) moved the direction of science education toward making physics, a lab-based science, more interesting and inspiring for the students. The report stated disagreements on how high school science laboratories are defined or the purpose they serve. Meltzer and Otero (2015) noted that the NRC report drew "attention to the preparation of teachers to facilitate investigation-based laboratory work in the classroom" as well as "increased engagement of students in science laboratory activity" (p. 454).

The lack of laboratory work is attributed to classrooms that are filled with teachers who are not qualified to teach physics. Unfortunately, studies support the fact that "students learn physics concepts best through experience, discovery, and the process of peer education" (Tesfaye & White, 2012, p. 4). Because of the fewer number of physics teachers available to meet the growing demands of students enrolled in America's physics classrooms, more students are often denied quality education (Banilower, 2013; National Center for Education Statistics [NCES], 2013; Sunal & Wright, 2016; White & Tyler, 2012). The growing need in the physics classroom calls for a content-focused professional development that targets this specific group of teachers to ensure students' learning needs are met (Desimone, Smith, & Ueno, 2006).

In a study conducted by Banilower (2013) to describe the status of high school physics, the researcher used survey method to collect data from a sample of 472 teachers in schools across the United States. The aim was to examine what influences teachers' decisions about content and pedagogy and what formal and informal opportunities physics teachers have for ongoing development to improve their knowledge and skills. Descriptive analysis of the survey data revealed that only 23% of the teachers had degrees in physics compared to 36% in other science subjects. The result also showed that traditional lectures and quantitative problem solving were mostly used by almost all the physics teachers and that "physics teachers were more likely to teach multiple subjects" than the other science teachers (p. 2). In addition, there was a "statistically significant decline in the total proportion of teachers with a major or minor in physics or physics education" (p. 4). This finding showed that the physics classrooms are filled with teachers who are less qualified to teach the subject and are, therefore, in need of professional development.

This need is even more for the advanced placement (AP) physics teacher. The AP curriculum is a preparatory college curriculum established by College Board to expand high school students' access to higher education. The curriculum was intended to prepare and provide avenues for students to become familiar with the rigor of college level coursework and as a platform for students to be more competitive for college admission (College Board research report, 2005-7). While enrollment in AP physics in growing, a 2013 statistics from the state department of education in a southeastern state show that unlike other science subjects only about 19% of students in the state enter college prepared to study physics, compared to 33% across the nation.

In a follow up study to an earlier national survey in 2008-09 of high school courses and enrollment, White and Tesfaye (2014) conducted a survey to determine the number students taking physics in high school. Survey data was collected from a representative sample of 3,553 schools and the result showed there was a slight growth in enrollments from the 1.35 million students in the 2008-09 survey to 1.38 million in the 2012-13 school year. The observed increase according to the report, came from courses other than “regular” physics. The report stated that 685,000 students enrolled in courses other than regular physics, an increase of over 560,000 students from the previous years. The researchers also noted that although there was an increase in the number of students taking physics, the increase is not matched by an increase in the number of qualified teachers. This shortage of teachers creates the challenge of providing high-quality physics education to the students (Meltzer & Otero, 2015; Paek et al., 2005). As more students enroll in the advanced placement program, the severe shortage of well-prepared physics teachers can hamper students’ participation and success in the program.

In a similar study, White and Tyler (2014) conducted a national survey with a representative sample of 3,858 high schools in the U.S. during the 2012-13 school year to determine who teaches physics in high school. They used two approaches based on a) the teachers’ educational background/degrees earned, and b) how often they taught physics to examine the level of physics teaching experience of the teachers. The survey data was completed by about 56% of the 3,702 teachers contacted. They found that although the number of students taking physics increased slightly from 1.35 to 1.38 million, the number of teachers remained unchanged from previous years. Only about 27,000 teachers taught at least one physics class during the 2012-13 school year.

Other studies have observed that the popularity of conceptual physics, advanced placement physics, and high school graduation requirement has driven physics enrollment, and now the challenge is how to fill the classroom with qualified physics teachers (Meltzer & Otero (2015). Hoddap, Hehn, and Hein (2009) agreed with these findings stating that only about 1/3 of teachers in physics classrooms have majors in physics or physics education. Although there are many devoted and highly qualified physics teachers, the overall situation for U.S. high-school physics students is not good, and "except for a handful of isolated pockets of excellence, the national landscape of physics teacher preparation shows a system that is largely inefficient, mostly incoherent, and completely unprepared to deal with the current and future needs of the nation's students" (Meltzer et al., 2013, p. 8).

Research on Professional Development Programs

Professional development is a key tool used to improve teachers' knowledge and practice. Fullan (2007) described professional development as "workshops, courses, programs, and related activities that are designed presumably to provide teachers with new ideas, skills, and competencies necessary for improvement in the classroom" (p. 35). It provides an avenue for teachers to be adequately prepared as agents of change for enhancement of students' learning and achievement (NSES, 2012; Paek et al., 2005). Escalada and Moeller (2006) believe that professional development can be effective in correcting a teacher's conceptual understanding and prevents the perpetuation of misunderstandings and misconceptions. Conversely, lack of effective professional development can deprive teachers the opportunity to be the best they can be in the classroom.

In a self-reported study conducted to understand the impact of science standards on teacher classroom practice, Sunal and Wright (2006) surveyed 141 elementary, middle, and high school teachers in a southeastern state of the United States. The survey data collected was quantitatively analyzed and the researchers found that many teachers were not meeting the state standards because they were not familiar or were confused about the goals and purpose of the standards, therefore they could not fully implement the standards in their classrooms. Sunal and Wright attributed the teachers' inability to effectively implement the standards to a "lack of adequate professional development for a majority of teachers" (p. 147). It is believed that when teachers engage in professional learning, their knowledge and skills are expected to improve in a way that makes a difference in their classrooms (Cole, 2012).

Although reform effort led "educational scholars and policy makers to demand professional development opportunities for teachers—opportunities that will help them enhance their knowledge and develop new instructional practices" (Borko, 2004, p. 3), not all professional development experiences can be defined as successful and fruitful because the needs of teachers are seldom met (Hill, 2009). Many AP teachers are faced with the challenge of teaching the course without the necessary background, conceptual understanding, experience and/or skills, and they find themselves learning the content along with their students (Klopfenstein, 2003; Parker et al., 2011).

To understand the effect of different characteristics of professional development on teachers' knowledge and ability to implement a program in the classroom, Penuel, Fishman, Yamaguchi, and Gallagher (2007) surveyed 454 teachers that participated in a two-year inquiry science professional development program. Twenty-eight professional development providers partnered to provide the training over the two-year period. Quantitative data was generated and analyzed within a hierarchical linear modeling framework using descriptive statistics and correlations of all items, factors, and indices. The result showed that participants' knowledge and preparedness toward inquiry was significantly impacted by the continuous training because of the core features of the program which focused on “content knowledge, active or inquiry-oriented learning approaches, and a high level of coherence with other reform activities and standards in the teachers’ local school contexts practice” (p. 924). These factors contributed to enhancing the content knowledge, pedagogical skills, and changes in the participants’ instructional practices.

High quality professional development is described in the *NCLB* Act (2001) as a) sustained, intensive, and classroom-focused; b) improve and increases teachers’ academic subjects knowledge; and c) increases teaching skills by substantially advancing teachers’ understanding of effective instructional strategies. High quality professional development also aligns with the goals and standards set by the state or district and provide “opportunities for collaboration so that teachers can learn from each other” (Teaching Commission report, 2004, p. 49).

In a case study to examine the impact of inquiry-based professional development on teachers’ core conceptions and teaching practices, Kazempour (2009) followed one teacher’s progress in an inquiry based continuous professional development program. The program provided a two-week summer training and three follow-up workshops during the academic year. The focus of the study was to better understand the experiences, changes in conceptions of teaching, and the factors that influence the classroom practice of participants. The research found that for professional development to be effective in enhancing and changing a teacher’s classroom practice, it must 1) be continuous over a period of time; 2) involve teacher active participation in authentic scientific inquiry-based activities and discussions and; 3) model effective inquiry-based practices.

In another study, Banilower, et al. (2013) conducted a national survey of 7,752 science and mathematics teachers to identify trends in teacher background and experience, curriculum and instruction, and the availability and use of instructional resources. The survey asked about the total amount of time participants had spent on professional development that was related to their content area. About 30% of middle and high school science teachers had participated in more than 35 hours of content-focused professional development in the last three years. It was concluded that a "brief exposure of a few hours over several years is not likely to be sufficient to enhance teachers' knowledge and skills in meaningful ways" (p. 34).

The national goal for effective professional development "is to increase responsibility and accountability for professional development programs to better equip teachers to teach a rigorous curriculum to all students and to ensure that students meet high standards" (Mundry & Boethel, 2005, p. 3). This can be achieved through on-going training. The National Research Council (NRC, 1996) noted that "becoming an effective science teacher is a continuous process that stretches from pre-service to the end of professional career" (p. 54) and that "teachers will need ongoing opportunities to build their understanding and ability" (p. 56).

Measuring Professional Development

Traditionally, professional development is measured with evaluation forms and surveys, which are largely designed to measure participants' perceptions, attitude change, and satisfaction of how well the course met participants needs (O'Brien & McIntyre, 2011). The Department of Education and the National Science Foundation (NSF) measures the impact of professional development by improved teacher quality on instruction and students' learning outcome or achievement. However, these measures seldom show the effect of professional development on the participants. Blank and De las Alas (2009) believe that "measurable effects are hard to demonstrate due to the lack of consistency, content focus, and coherence among the professional development activities provided" (p. 4). A guideline was therefore needed that will guide how to measure the effectiveness of professional development on the participants.

Framework on Effective Professional Development

A guide to measuring the effectiveness of professional development advanced by Desimone (2009) is gaining acceptance as a conceptual framework in the research literature. The core features of the framework are commonly used in empirical research and has been linked to effective professional development. *Content-focus,* professional development should provide content knowledge development for teachers and knowledge of how students learn that content; this is the most important feature of professional development. Birman, Desimone, Porter, and Garet (2000) believe "the degree to which professional development focuses on content knowledge is directly related to teachers' reported increases in knowledge and skills" (p. 30). Other empirical research also suggests that content-focused professional development influences teachers' knowledge, teaching practice, and student learning (Ingvarson et al., 2005; Rock, Courtney, & Handwerk, 2009; Smith, Desimone, & Ueno, 2005); *active learning* involves "engaging teachers as learners" through active participation in activities during the training. Teachers should provide and receive feedbacks and not be passive participants. Ingvarson et al. (2005) noted there is a positive relationship between active learning during professional development and teachers' knowledge or teaching practice. *Duration* should provide an adequate period for sustained learning. The professional development activities should be long enough to provide the teacher with adequate time to utilize the information. Yoon et al. (2007) found that professional development that provided 30 to 100 hours of continuous training had a statistical significance and positive effect on student achievement gains compared to those with five to 14 hours. *Coherence* is the extent to which professional development is consistent with the teacher learning opportunities, teachers' knowledge and beliefs, teacher school, district, and state reforms and policies (Desimone, 2011). It is the degree to which professional development activities are aligned and consistent with the teachers' goals and assessments, and how it promotes the discourse among teachers concerning their work. *Collective participation* in professional development should provide opportunities for teachers to collaborate with their colleagues within the context of the training. This fosters professional learning community (PLCs). A positive association was found between collective participation and teaching practice (Desimone, 2011; Meltzer, Plisch, & Vokos, 2012; Penuel et al., 2007). Desimone's (2011) conceptual framework is shown in Figure 1.

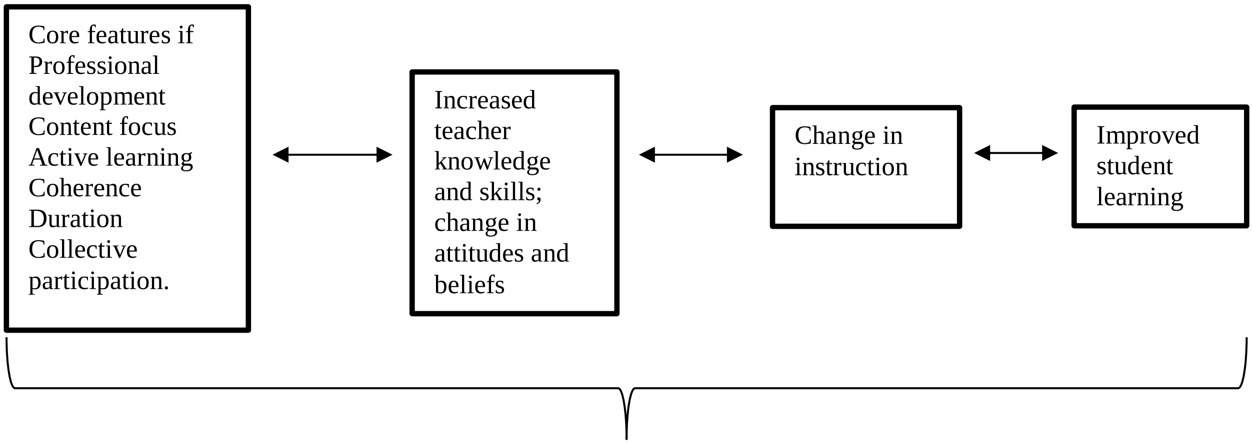


Figure 1. Desimone's conceptual framework on effective professional development

Desimone's (2011) framework provides a dual platform for testing the theory of teacher change; how professional development alters teacher knowledge, beliefs and practice, and the theory of instruction; and how changed practice influences student achievement. Both of these processes are necessary to understand how professional development works (Wayne, Yoon, Zhu, Cronen, & Garet, 2008).

A survey study conducted to determine if features of professional development programs were influencing participants' classroom practices and student outcomes, O'Brien and McIntyre (2011) collected data from 6,928 school principals and teachers. The study examined participants' views on the effectiveness of select professional learning courses and programs undertaken by the staff of the school based on Desimone's (2009) impact framework. Quantitative analysis of the data found that all five features of professional development prescribed by Desimone (2009) were present in the professional development programs experienced by the participants and that there was evidence that the professional development program had positive effect on teachers' classroom practice and student learning outcomes.

In a case study to identify the degree to which participating in a three-year professional development program affected participants' content knowledge and use of inquiry, Jeanpierre, Oberhauser, and Freeman (2005) collected quantitative and qualitative data from 20 middle and high school teachers, and 86 students that completed the one-week institute. The mixed data was generated from surveys, classroom visits, interviews, and field notes to determine if the teachers translated their experiences into instructional practices. They also examined the effectiveness of the professional development program in increasing the teachers' science content understanding by obtaining a baseline data on teachers' knowledge before they participated in the institute. An identical post-assessment was also conducted at the completion of the institute to allow for comparison of change in teachers' knowledge. The finding showed a gain in teacher knowledge and that the teachers were able to translate the gains to their classrooms. Jeanpierre et al. noted that key characteristics of the professional development allowed the teachers to successfully translate the gains to their classrooms. The features identified included the increase in science content and process knowledge, opportunities for practice, and the requirement that teachers demonstrate competence in a tangible and assessable way. These characteristics were shown to increase the effect of the professional development on teachers' instruction.

Effective professional development adds to a teachers' repertoire and enhances their PCK. Bennett (2010) stated that "increasing teachers' instructional repertoire we are more likely to become artful or creative and more scientific or intentional when differentiating our instruction to meet the diverse needs of students" (p. 69). Increasing a teacher's repertoire also increases the use of reform teaching in the classroom. The effect of increasing the teachers' repertoire for the physics teacher is that it helps in how particular physics topics/concepts, problems, and issues are organized, presented, and modified for the different levels of learners in the classroom (Crouch, Watkins, Fagen, & Mazur, 2007; Fisher, 2004).

For effective and reform-oriented teaching to take place in the physics classroom, the teacher must be adequately prepared and equipped in content and instructional strategies in order to meet the needs of the student. Because many teachers do not experience reform-based learning themselves as students, professional development should integrate components that help teachers develop high levels of physics PCK (Etkina, 2010). Zhang, Parker, Koehler, and Eberhardt (2015) noted that although PCK is used as a teacher's knowledge base; "few professional development programs seem to focus on the topic-specific nature of teacher knowledge" (p. 475). Many teachers view professional development programs as opportunity for renewal since "they become students themselves and thus engage their own existing knowledge in the course of acquiring new knowledge" (Rozenszajn & Yarden, 2014, p. 207). Therefore, professional development should have an impact on teachers' knowledge and teaching (Tytler, Symington, & Smith, 2009). The effectiveness of professional development depends on its definition, and core features which can be used to evaluate if a professional development program is meeting the desired result of “increasing teacher knowledge and instruction in ways that translate into enhanced student achievement” (Desimone, 2009, p. 68).

Research on Teacher PCK

The concept of pedagogical content knowledge (PCK) was introduced by Shulman in 1986. PCK is ‘‘the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to diverse interests and abilities of learners, and presented for instruction’’ (p. 8). When content knowledge and pedagogical knowledge are integrated, teachers acquire the PCK needed to promote effective teaching and positive students’ learning (Abell et al., 2009; Loughran, Berry, & Mulhall, 2006; Okonlawon, 2010; Shulman 1986, 1987). The Association for Science Teacher Education’s (ASTE, 1997) policy statement on Professional Knowledge Standards for Science Teachers provides a set of generic standards for all science teachers that serves as a guideline for science teaching. The three guidelines fall within the Shulman (1987) construct: content knowledge, pedagogical knowledge, and pedagogical content knowledge, which has been widely discussed and researched. Although there are other categories outlined by the construct, this study focused on these three categories.

Content Knowledge (CK)

Content knowledge represents a teacher’s understanding of the subject matter being taught. Content knowledge is central to the development of PCK because it is dynamic and transforms different types of knowledge (Abell, 2008). A science teacher needs content knowledge to promote students’ understanding because “teachers who do not themselves know a subject well are not likely to have the knowledge they need to help students learn *the* content” (Ball, Thames, & Phelps, 2008, 404) (*emphasis added*). A teacher grounded in the subject matter is able to “ask questions that enable the learner make sense of their own understanding” (Findel, 2009, p. 18). Anderson and Freebody (2012) believe a teacher with deep understanding of the content is effective, regardless of the context, in making connection with other ideas, providing the learner with meaningful experience that leads them to know. Conversely, the lack of sufficient content knowledge limits innovative practices and choice of materials for teaching the concept. Baumert et al. (2010) believe that teachers’ repertoire of teaching strategies is largely dependent on the breadth and depth of their conceptual understanding of the subject.

Pedagogical Knowledge (PK)

Pedagogical knowledge forms the basis for transforming content knowledge to knowledge that can be domain-specific. Pedagogical knowledge includes the declarative and procedural knowledge needed to create effective teaching and learning opportunities. It encompasses knowledge of classroom management, knowledge of teaching methods, knowledge of classroom assessment, knowledge of learning processes, and knowledge of individual student characteristics (Voss, Kunter, & Baumert, 2011). The knowledge is acquired over a period and throughout the professional career and provides teachers with the understanding of the students, and the internal or external factors that influence classroom instruction, and also makes it possible to integrate and use activities that address the needs or demands within a given classroom context. Findell (2007) stated that pedagogical knowledge enables the teacher to self-regulate, be resourceful, and creatively develop alternative plans based on the flexibility of having the knowledge. The teacher can adjust more readily to the context by making sense of the dynamics of the class.

Pedagogical Content Knowledge (PCK)

Pedagogical content knowledge is teachers' unique knowledge based on the blending of their content knowledge—the knowledge of the subject they teach and their pedagogical knowledge—the knowledge about how to teach the content. It is "the category most likely to distinguish the understanding of the content specialist from the pedagogue" (Shulman, 1987, p. 8). PCK is the understanding a teacher has that embraces the purpose and goals of teaching and the assessment criteria used for students' learning of specific goals and ideas (Sunal, 2014). When content knowledge (CK) and pedagogical knowledge (PK) are integrated, they enhance teaching and produce meaningful learning and expected outcome. PCK is what transforms subject matter knowledge in a way that makes it effective and flexible for both the teacher and learner. Loughran et al. (2004) noted that the blending together of teacher pedagogy and understanding of content as what influences teachers in ways that best engender students' learning for understanding. The PCK framework is shown in Figure 2.

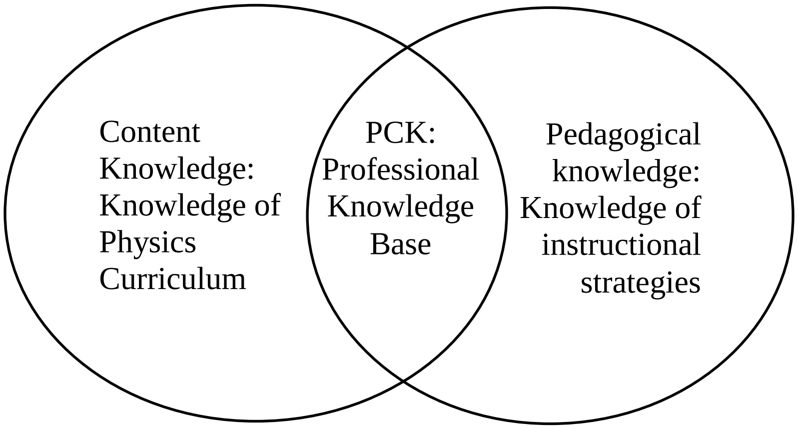


Figure 2. The PCK concept

Teachers that are effective in the classroom often "employ components of PCK in an integrated fashion as they plan and carry out instruction" (Abell, 2008, p. 1407). Although the concept of PCK is widely regarded as the teacher professional knowledge base, conceptualizing it is a complex issue because of the multiple models and approaches that have been used in studies to capture the process acquisition. While some models are focused on the teaching-learning process from the teaching perspective, others chose to investigate the construct from the learning perspective of the students. But whatever lens is used to capture the construct, there is a growing consensus that PCK should be a focus of teacher professional development because of its impact on teacher effectiveness and knowledge (Abell et al., 2009; Bausmith & Barry, 2011; Hashweh, 2013; Kind, 2009; Shulman, 1986, 1987; Tytler et al., 2011; Van Driel & Berry, 2012).

In a study of three experienced high school biology teachers, Rozenszajn and Yarden (2014) used grounded theory approach to examine if participating in a long-term (two-year) professional development expanded the teachers' PCK. The focus of the workshop was to enhance teacher PCK by enriching the participants' knowledge of contemporary biology topics and science education theories. Qualitative data was collected from discussions, teacher interviews, and workshop materials. Data analysis showed that the program provided a meaningful platform that expanded the teachers' PCK and that while each teacher was influenced by different activities at different levels, all three teachers' experienced meaningful expansion of their PCK during the final stage of the program.

In a similar study to examine science teachers' need for professional development, Zhang et al. (2015) used the PCK framework to gain insight into the teachers' self-perceived needs for professional development. They surveyed 118 science teachers, 96 females and 22 males, who participated in a professional development program over a three-year period. The participants selected two topics of their choice and rated the extent of improvement they needed on a 5-point

Likert scale based on nine PCK component with 1 indicating ‘‘needs no development’’ and 5 indicating ‘‘needs a lot of development. Analysis of the data involved the use of descriptive statistics, one-way ANOVA, and t-test. The result showed multiple areas of need on teacher PCK, instructional strategies, the curriculum, and assessment. Of these needs, inquiry posed the greatest challenge as identified by most teachers. The researchers concluded that effective professional development “should teach teachers what they need to know and help them deal with challenges arisen from practice” (p. 473) and that teachers “cannot effectively teach any topic without solid content understanding” (p. 474).

A similar study conducted to examine the relation between a teacher’s PCK score and the degree to which his/her instruction is reform-oriented, Park, Jang, Chen and Jung (2010) used a correlational research design to study seven high school biology teachers. They used 33 instructional training sessions and collected pre- and post-test interviews in addition to classrooms observations. A PCK rubrics and the Reform Teaching Observation Protocol (RTOP) instruments were used for data collection. The study result showed that the teachers’ PCK scores were directly related to the reformed teaching observation protocol (RTOP) rating and that the “level of a teacher’s PCK is highly connected with the degree to which his or her instruction is reform oriented” (p. 252).

Pedagogical content knowledge goes substantially beyond what is typically taught in colleges and universities. Sadly, with a few exceptions, a majority of subject matter courses for teachers and teacher education programs have little bearing on the classroom realities and little effect on improvement of teaching and learning as they tend to be very academic in subject matter courses in ways that are remote from classroom teaching (Ball et al., 2008). PCK is "dynamic because teachers develop it over time as they use the new knowledge and teaching strategies from professional development and classroom experience" (Abell, 2008, p. 1407).

The role of PCK in physics education like other subject areas cannot be overemphasized. Both content knowledge and pedagogical knowledge must be present for effective teaching and learning of physics. Ojose (2012) noted that "common sense dictates that we cannot teach what we do not know: content knowledge is needed. In the same reasoning, we cannot effectively teach content we know quite well if we lack knowledge of teaching" (p. 151). Lederman and Gess-Newsome (2011) observed that teachers with physics PCK are more likely to facilitate meaningful learning outcomes in secondary school students.

Professional Development and Advanced Placement Physics

The College Board

Because of the growing enrollment in AP physics coupled with the need to fill those physics classrooms with qualified physics teachers, the College Board strongly recommends that AP teachers participate in summer training/workshop (College Board, 2012b). The College Board provides a five-day training with the aim of developing teachers to learn "specific pedagogical techniques and content-specific strategies that can be incorporated in the classroom" (College Board, 2015-16, p. 3). During the training, released AP exams materials, subject specific course description, and teacher's guide are reviewed. Additional one- or two-day workshops are also provided during the year. The goal is to 1) align instruction with the goals of the AP course; 2) identify the skills and knowledge the exam will assess; and 3) determine the tasks and materials for which students may need more preparation, etc. Participants are provided with AP content-related handouts, student samples, exam scoring guidelines and pacing charts to help teachers learn how to develop activities, assessments, and laboratory strategies that engage students in acquiring the skills needed to excel in AP courses.

In a study to better understand AP teacher practices and effectiveness in promoting students' passing rate following the College Board training, Paek, Ponte, Sigel, Braun, and Powers (2005) collected survey data from 1,171 (AP) Biology and 1,219 (AP) U.S. History teachers. Focus group interviews were also conducted to generate qualitative data. A descriptive analysis of the data showed that 30% of the AP teachers have never attended a College Board AP workshop but, that those who did followed the strict guidelines prescribed by the College Board training. They also found most of the teachers favored instructional strategies that involved a shorter time frame to cover a larger amount of content over highly involved and time consuming strategies; therefore, based on the training, 84-92% of the participants used mostly lecture as the predominant method of teaching. The researchers noted that the current research-based methods of how students learn were largely not used.

The Alliance for Physics Excellence (APEX)

The APEX professional development is a statewide project funded by the National Science Foundation (NSF) as part of the Mathematics and Science Partnership Program (Sunal, et al., 2014). The professional development program was designed with the goal of transforming physics education in a southeastern state by enabling in-service physics teachers to acquire a deeper content knowledge of physics. The program enables teachers to employ effective pedagogical strategies and activities in their classrooms that the research literature reports are effective in the learning of physics and will enable students to achieve higher achievement gains. APEX differs from other professional development programs in the state because it provides a three-year continuous training that includes two weeks of intensive summer training and additional three two-day weekend workshops throughout each of three successive academic years. APEX provides physics-focused professional development that is not commonly available to teachers by assessing the needs present in the physics classrooms. The over-arching premise of the professional development model is to provide research-based content and pedagogic strategies that afford teachers with opportunities to develop their content knowledge and pedagogical skills that change their instructional practices. Participants are drawn from public high schools in the rural, urban, and suburban areas of the state. The professional development evaluates participants' progress through pre- and post-training assessment to identify changes in practices and growth in the teachers. Teachers participate actively in reform-based activities during the training and are provided resources that are used in the classroom. The teaching strategies/activities and resources used during the training sessions are research based and have been shown to promote reform teaching practices in the classroom.

For each science content area, it is expected that teachers will possess and regularly update the knowledge base needed and relevant for their core professional practice. The shortage of physics teachers in high school classrooms, coupled with the rigor in the advanced placement curriculum, demands that these teachers engage in professional development programs that are grounded in academic content that provide continuous effective training which enhances the teachers' knowledge base and the implementation of reformed teaching. This will enable them improve their practice and meet the new teaching demands in the 21st century.

Physics Teaching and the School Context

School and classroom context play a vital role in providing a positive setting for teaching and learning. Student learning takes place within classroom settings which typically have students with diverse abilities and learning needs. This creates a complex social framework of interactions in the teaching and learning process and it can pose some challenges for teachers who have to know how to structure and orchestrate learning opportunities accordingly (Voss et al., 2011). For the AP physics classroom, a wide range of contextual factors strongly predict students' participation and achievement in physics education. These factors may include teacher quality; teacher preparation and experience, school climate/leadership, teacher instructional methods and schedule, teacher instructional resources and technology, student motivation/engagement, student socioeconomic status, school type (e.g., rural, urban or suburban) and can individually or collectively contribute to the effectiveness or lack of effectiveness of teaching and learning.

Since school context can moderate the efficacy of instructional practices, it is important to understand its nature and establish the links between teacher practice and student achievement (Peak et al., 2005). Because teacher experiences are set in contexts in which these forces influence their professional beliefs and teaching practice, it is necessary to consider contextual variables when evaluating the impact of effective professional development (Kang et al., 2013). Also, because teachers often work within a broader contextual framework beyond their classrooms such as the school, the effectiveness of professional development interventions should be described within the context of the functioning settings (Yoon, 2008).

To determine the effect of different characteristics of professional development on teachers' knowledge and their ability to implement the programs in the classroom, Penuel et al. (2007) examined the GLOBE network of professional development partners. They collected quantitative and qualitative data using survey and face-to-face interviews from 454 teachers who participated in a long-term professional development program. Their finding showed there was no significant change in teacher knowledge and change in teaching practice after initial professional development from the GLOBE partners; however, after additional professional development, the teachers had a significant impact on teacher content knowledge and were able to implement the knowledge gained in their classroom. This showed that there was a positive impact on teachers' instruction because the professional development activity aligned with participants' school and district policy. Cole (2012) believes that professional development can have an impact on classroom practices if the design and implementation meet the need of teachers in the particular setting where the knowledge is used. Opfer and Pedder (2011) agreed that teacher professional learning should be conceptualized to reflect "the complex teaching and learning environments in which teachers live" (p. 377).

In a study to examine the outcomes of a research-based systemic professional development program for teachers in the vocation and education training sector, Saunders (2014) used mixed method design to collect survey data, questionnaires, teacher interviews, and classroom observation from 27 teachers who participated in a long-term professional development program. Part of the study was to determine if teachers changed their instructional practices as a result of the professional development program and to identify what facilitated or hindered teachers' implementation of instructional innovations. Analysis of the qualitative and quantitative data indicate that "teachers mold their practices to suit the needs of their immediate environments because what may work for one teacher in one context may hinder another in a different situation" (p. 167). Saunders suggested that it is important when designing professional development programs to consider what happens when teachers attempt new practices and processes in their work settings because enacting new practices and processes often involves negotiating through a host of variables that include "student behaviors and abilities, relationships with colleagues, school climate, availability of resources and competing policy imperatives" (p.

167). These variables can potentially either support or impede effective implementation resulting in teachers having different experiences.

When professional development reform is not aligned with the school context, teachers do not adopt and implement the improved teaching in their classrooms (Desimone et al., 2002; Main & Virtue, 2015). This means that knowledge from professional training alone is not enough to make the desired change in the classroom. Fullan (2007) noted that “the notion that external ideas alone will result in changes in the classroom and school is deeply flawed as a theory of action” (p. 35).

In a case study to measure the impact of professional development intervention on science teacher practices and students’ achievement, Buczynski and Hansen (2010) collected qualitative data using focus group, pre- and post-subject matter exams, teacher surveys, classroom observations, and student achievement scores from 118 science teachers and 3,450 students from two urban school districts. The researchers aim was to determine if the teachers implemented the knowledge gained from professional development. They found that contextual barriers prevented the successful implementation of the new ideas. The professional development curriculum was hindered by multiple contextual factors such as lack of time allotted for science instruction by school sites/districts, mandates to teach a certain curriculum, lack of resources, and classroom management issues were part of the reasons stated for the lack of successful implementation.

In addition to having unqualified teachers in the classroom and the constraint of instructional time, which affects the quality of instruction in any environment, the lack of adequate school resources affect the capacity to implement the curriculum effectively (Lee & Zuze, 2011). Schools serving students of lower socioeconomic status have difficulties recruiting highly qualified teachers, and they lack some of the basic resources that promote student success and higher achievement (Schleicher, 2012).

A TIMSS (2011) report supported this finding adding that students in schools that are sufficiently resourced generally have higher achievement compared to schools where there are shortages in resources. Contextual factors often interact to form a complex structure that seeks to inhibit teaching and learning of any subject. Therefore, professional development should align with the school/district curriculum or be embedded in the school/classroom context, thereby facilitating an increased acceptance of ideas from the training. Successful implementation of research-based instruction from professional development is dependent on the alignment of prescribed methods/strategies with the structure of the school/district (Paek et al., 2007; Saunders, 2014; TIMSS, 2011). Peak et al. (2007) noted that "schools and districts that embrace and implement the gains from the professional training intervention tend to notice improvement in students' learning" (p. 2). Desimone (2009) called this *coherence*, a key feature of professional development that enable teachers align reform practices within the demands of the school.

Theoretical Model of Research Study

Content focused professional development is the wheel that drives teachers' content knowledge (CK) and pedagogical knowledge (PK). As the two components improve and are integrated, they lead to enhanced pedagogical content knowledge (PCK) over time due to continuous practice. Teachers need adequate PCK to implement reform-oriented instruction in the classroom. Literature highlights the importance of continuous content focused professional development and how it impacts teacher implementation of effective instructional practices in the classroom. Studies show that there is a direct correlation between teacher PCK and the use of reform practices in the classroom (Desimone, 2011; Loughran, Berry, & Mulhall, 2006; NRC, 1996; Okonlawon, 2010). The role of professional development is to add to the teachers' repertoire by improving teachers' content knowledge and pedagogical knowledge which together develops into a knowledge base needed to improve classroom instruction. Because content knowledge, pedagogical knowledge, and pedagogical content knowledge are intertwined, this study utilized the model shown in Figure 3 to illustrate the nexus between the three components.

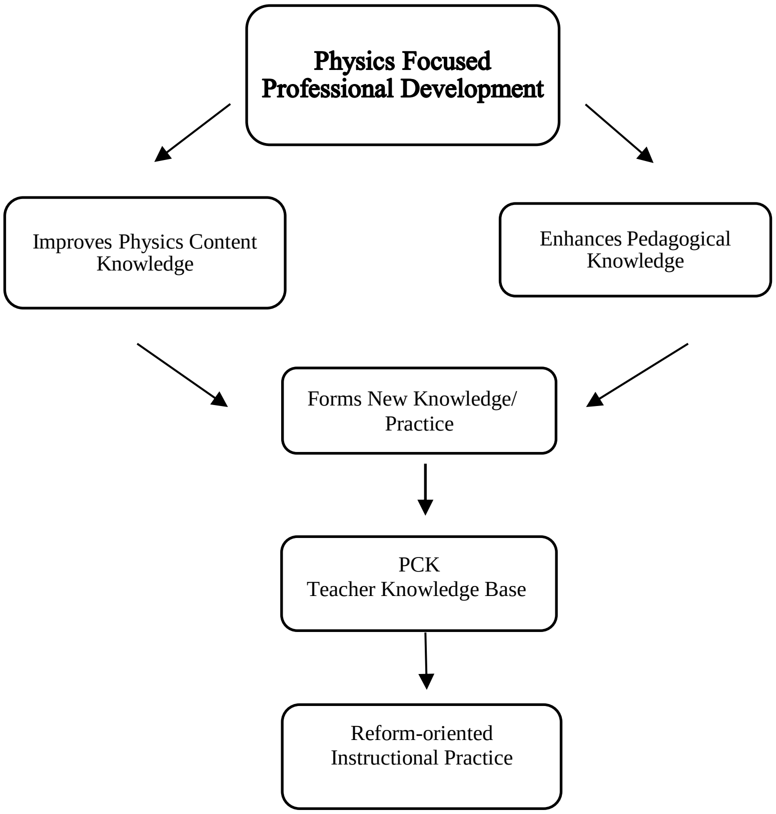


Figure 3. Model of research study

Instrumentation

To address the research questions in this study, a mixed methodology was used to collect data from multiple sources that include classroom observations, interviews, surveys, and questionnaires. The *Reformed Teaching Observation Protocol* (RTOP) instrument provided the quantitative data while the qualitative data was collected from the *Content Representation*

(CoRe) interview and researcher notes, which were delineated to create the *Pedagogical and Professional-Experience Repertoires* (PaP-eRs). The Physics Teaching Efficacy Belief Instrument survey *(PTEBI-A)* and TIMSS AP physics teacher questionnaire provided demographical data.

The *Reformed Teaching Observation Protocol* (RTOP) is an instrument introduced by Pilburn et al. (2000) and Sawada et al. (2002). It was designed as a classroom observational tool to measure the degree of reformed teaching in science classrooms. The instrument is divided into five sections: (1) lesson design and implementation; what he teacher intended to do to support student understanding of the lesson, (2) propositional content knowledge include teacher content knowledge, organization and presentation of material, (3) procedural content knowledge; what the students did, type of instruction used to engage them, (4) classroom culture (communicative interactions); how the teacher facilitated interactions among the students, and (5) classroom culture (student–teacher relationships); the culture of respect and comfort supported by the teacher and learners. Each section contains five items which are rated from 0 (never occurred) to 4 (very descriptive). The total RTOP rating ranges from 0 to 100, with higher rating representing teaching that is more reformed. The RTOP has been validated extensively by multiple research studies and has a reliability rating of 0.954 (Piburn & Sawada, 2000).

In a mixed method study that examined the impact of modeling instruction on participating teachers' instructional practices, Barlow, Frick, Barker, and Phelps (2014) purposefully selected nine participants in the project TIME professional development program. Participants' classrooms were observed before and after the training with the RTOP instrument. Teachers were also interviewed with an interview protocol instrument. Analysis of the quantitative data from the RTOP instrument showed that all but two participants demonstrated increase in their total RTOP scores. This means there was increased level of reform by the teachers. The two participants that did not score high on the RTOP scale cited external challenges that prevented the implementation of the gains from the professional development.

In another research that used an interpretive study to examine how teachers' belief influenced the use of inquiry, Lotter, Rushton, and Singer (2013) observed 36 high school teachers' classroom using the RTOP instrument after the teachers participated in a two-week professional development program. They also used a series of interviews to investigate the teachers' beliefs about inquiry instruction. Based on the RTOP rating, they found that teachers' enactment of inquiry fell into four levels: integrated, emerging, laboratory based, and activity-focused and that the teachers needed a strong conceptual understanding of inquiry-based teaching to implement inquiry practices.

To determine if PCK was necessary for science reform teaching, Park et al. (2010) used the RTOP instrument in a quantitative study to measure the degree of reform-oriented instruction in the classroom of seven high school biology teachers. They investigated the correlation between a teacher's PCK level and level of reform in the classroom using a PCK rubric and found the "level of a teacher's PCK is highly connected with the degree to which his or her instruction is reform-oriented" (p. 252). These studies support the use of the RTOP as a valid instrument in assessing the level of reform-oriented practices in the science classroom.

The *Science Teaching Efficacy Belief Instrument* (STEBI-A) is an instrument created by Riggs (1988) and developed by Enochs and Riggs (1990) to assess in-service science teachers' personal self-efficacy belief. STEBI-A has two distinct subscales, the personal science teaching efficacy (PSTE) and the science teaching outcome expectancy (STOE). The PSTE scale measures teachers’ beliefs in their own ability to teach science and has a reliability rating of (α = 0.92), while the STOE assesses teachers’ beliefs that student learning can be influenced by effective teaching. The STOE has a reliability of (α = 0.77). A modified version of STEBI-A was used for this study. The word science in STEBI was replaced with physics (PTEBI) to make the instrument more physics focused. The word science was also replaced with physics in the PSTE and STOE subscales and used PPTE and PTOE respectively. The instrument contains 23 items with 10 written in positive language and 13 written in negative language. All items on the instrument are on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Science teaching efficacy has been well researched and validated as a reliable tool for examining teachers’ self-efficacy beliefs toward the teaching of science.

To examine the impact of standard-based professional development on teacher efficacy and instructional practice, Lakshmana, Heath, Perlmutter, and Elder (2011) conducted a three-year longitudinal study using direct classroom observations to observe changes in participants’ practices. Two instruments, STEBI-A and RTOP, were used to assess teacher efficacy and reform-oriented practices of the participants respectively. The researchers found significant growth in teacher self-efficacy and significant growth in the extent to which teachers’ implemented inquiry-based instruction in the classroom. They also observed a positive correlation between changes in the use of inquiry-based instructions and changes in teacher self-efficacy.

In a similar study to assess elementary teachers’ science teaching efficacy, Lumpe et al. (2012) used the STEBI instrument to examine how teachers’ beliefs about teaching science improved as they participated in a long term professional development program. Participants included 450 elementary school teachers who were involved in six two-week long summer programs that used inquiry-based instruction, science content knowledge, and science process (content focus) activities. Although the teachers showed no gains in outcome expectancy beliefs, there was significantly more positive gains in teacher self-efficacy beliefs as a result of the professional development training. The gain led to positive benefits for their students' achievement according to the researchers. The researchers concluded that teacher beliefs were positively impacted by the number of hours teachers participated in the research-based professional development program and this was significantly predictive of students' science achievement.

A person's self-efficacy and belief is often based on the personal judgments of competence to execute a particular task based on acquired or mastered skills used to effect a desired outcome. Erlich and Russ-Eft (2011) noted that it is "one's confidence in engaging in specific activities that contribute toward progress to one's goal" (p. 5). The physics teacher's perceptions of their skills and ability can influence the teaching and learning of the subject.

The *Content Representation* (CoRe) and the *Pedagogical and Professional-Experience Repertoires* (PaP-eRs). CoRe provides the interview protocol used to access teachers' knowledge and how they conceptualize and make decisions to teach a particular science concept and the PaP-eRs provides a narrative that combines the classroom observation and the CoRe interview to get a more holistic understanding of the teacher's PCK. Loughran et al. (2004) noted that it is important to consider the context of teaching and learning when determining the validity of the CoRe and PaP-eRs.

To properly document the PCK of four researchers, Garritz, Padilla, Ponce-de-Leon, and Rembado (2007) investigated the professors' ways of thinking of amount of substance when teaching a chemistry concept. They sought to validate Loughran et al.'s (2004) CoRe and PaP-eRs methodology in evaluating PCK. After conducting the classroom observations and interviews, they concluded that Loughran's method helped to uncover, document, and portray the professors' PCK. They acknowledged that the CoRe eight central idea questions were useful in identifying what the professors believed to be the main ideas in teaching the particular content.

The *Trends in International Mathematics and Science Study* (TIMSS, 2015) AP teacher questionnaire was used in this study to provide demographic information such as participants background information, age, sex, AP physics teaching experience, educational qualifications, etc. All these instruments have been extensively used and are well validated by many research studies. The reliability of the instruments has also been well established and documented. A summary of the instruments and the construct measured is shown in Table 1.

Table 1

Summary Description of Instruments and Constructs Measured

Construct	Instrument	Description
Level of Reformed-Oriented Teaching	The Reform Teaching Observation Protocol (RTOP)	The RTOP (Sawada et al., 2002) was used to evaluate the level of reformed teaching practices enacted in the teacher's lessons/classroom. The instrument can be rated from zero (never occurred) to four (very descriptive). A pre- and a post RTOP was collected from the teachers to evaluate any evidence of change.
Teacher PCK	CoRe Interview RTOP PaP-eRs PTEBI-A AP Questionnaire	The *CoRe* was used to determine participants' content knowledge and the decision-making process in teaching a particular physics concept. The *PaP-eRs* described action knowledge displayed by the teacher in teaching a physics concept. Both instruments will provide detailed insights into participants' PCK in teaching AP physics.
		The STEBI-A was designed to measure the level of self-efficacy and outcome expectancy in science teacher/teaching (Riggs & Enochs, 1990). It is divided into two categories: (1) Personal Science Teaching Efficacy-measured teacher's thoughts about their ability to effectively teach physics and (2) Science Teaching Outcome Expectancy (STOE). Both subscales captured teachers' ideas and belief about their physics teaching ability/skills and how that influence the outcome of students' learning.
School Context and AP Physics teaching	CoRe Interview PaP-eRs PTEBI-A AP Questionnaire	This questionnaire was used to provide information about the context or environment for teaching AP physics. The instrument covers: (a) the teacher/efficacy, b) Teaching AP physics/subject efficacy, and c) school context/contextual factors influence the teaching of AP physics.

The *PCK Essential Component Rubric* (Ogodo, 2017). This instrument was developed by the researcher based on essential components of Shulman PCK (1986, 1987), Loughran et al. (2006) CoRe interview instrument, and researched literature on content knowledge (CK), pedagogical knowledge (PK), and pedagogical content knowledge (PCK) to capture the teachers' pre- and post-intervention PCK and to identify the changes that occurred as a result of the APD training. Each item on the PCK Essential Components Rubric was scored on a Likert type scale of 0 to 4 with 0 indicating the item was missing, 1 = not adequate, 2 = needs improving, 3 = adequate, and 4 = descriptive. A teacher's score could range from the lowest possible score of 0 meaning none of the 15 items were observed to 60 the highest possible score. The rating was divided into three levels: rating of 0 – 20 = low PCK; 21 – 40 = medium PCK; and 41 – 60 = high PCK. Some components of the RTOP ratings were integrated into the rubric to provide additional information. **The RTOP components were noted with an asterisk.** The PCK Essential Components Rubric is shown in Table 2.

Table 2

PCK Essential Component Rubric

CK	PK	PCK
1) Has content knowledge to promote students' conceptual understanding / help students learn *the* physics content.*1 2) Uses questions that enable the learner make sense of the concepts.*8 3) Makes connection with other ideas, real life experiences, and provides the learner with meaningful experience that leads them to know the concept.*10 4) Displays a repertoire of effective teaching strategies based on the conceptual understanding of the subject. 5) Chooses innovative materials for teaching the concept.	1) Transforms content knowledge to effective teaching and learning.*5 2) Knowledge and understanding of students' thinking and learning processes. 3) Knowledge of effective classroom assessment. 4) Integrate and use activities that address the needs or demands within a given classroom context. 5) Knowledge of internal or external factors that influence classroom instruction.	1) Blends the content knowledge and the pedagogical strategies on how to teach the content. 2) Displays confidence in understanding of the content as a content specialist that distinguishes them from the pedagogue (novice) 3) Uses effective assessment to guide the teaching for students' learning of specific goals and ideas. 4) Enhances teaching by producing meaningful learning and expected outcome.*19 5) Provides overall effectiveness and flexibility for both the teacher and learner.
(Abell, 2008; Anderson & Freebody, 2012; Ball, Thames, & Phelps, 2008; Baumert et al., 2010; Findel, 2009; Shulman, 1986, 1987)	(Findell, 2007; Voss, Kunter, & Baumert, 2011; Shulman, 1986, 1987)	(Abell et al., 2009; Loughran, Berry, & Mulhall, 2006; Loughran et al., 2012; Okonlawon, 2010; Shulman, 1986, 1987; Sunal, 2014)

Summary

Based on the review of literature, it is evident that preparing a workforce for the 21st century depends on qualified teachers. *No Child Left Behind* (NCLB, 2001) defines a highly-qualified teacher as

> having completed a teacher education program and earned a bachelor's degree, thereby obtaining full state certification; being placed in a position which matches his/her area of certification; and not having had certification or licensure requirements waived on an emergency, temporary, or provisional basis. (Marszalek, Odom, LaNasa, & Adler, 2010, p. 3)

Unfortunately, while teachers may have highly qualified status in their subject areas, they may not be highly qualified in the subject they teach. Literature documented that while the number of high school students taking a physics course have increased significantly over the years, the increase has not been matched by the number of qualified teachers in those classrooms (Banilower, 2013; White & Tesfaye, 2014; White & Tyler, 2014).

To increase the number of qualified teachers, in-service teachers must participate in professional development program that are effective in enhancing their content knowledge and pedagogical skills. But, this is not often the case. Most professional preparation of science teachers has been largely inefficient and mostly incoherent, making the teacher completely unprepared to deal with the current and future needs of the nation's students (Meltzer et al., 2012; Paek et al., 2010; Sunal et al., 2016). Teachers who participate in a continuous content-focused professional development have been shown to favor inquiry-based instruction which create positive changes in their classrooms (Blank & de las Alas, 2009; Kazempour, 2009; Smith et al., 2007; Penuel et al., 2007).

In addition, contextual factors should be considered when examining the goals and objectives of professional development models because they influence the teachers' practices and the successful implementation of gains from the training (Paek et al., 2010; Saunders, 2014). When professional development reform is not aligned with the school context, teachers do not adopt and implement the improved teaching in their classrooms (Barlow et al., 2014; Desimone et al., 2002; Main & Virtue, 2015; Saunders, 2014).

As education policies continue to push for teacher accountability, high-stakes testing, and data-driven decision making, there is a need to equip teachers to meet the demands and responsibilities of today's physics classroom. Effective professional development provides the avenue for teachers to acquire and improve the skills-sets that make teaching and learning more meaningful for both the teacher and the learner. A summary of these key studies is shown in Appendix A.

CHAPTER III:

METHODS

The literature review in Chapter II showed that there is an existing consensus among researchers that effective professional development improves teacher quality and students' learning (Borko, 2004; Desimone, 2011; Ingvarson et al., 2005; Paek et al., 2005). The literature also showed that for professional development to have an effect, it must be continuous, and it should provide opportunities for teachers to work with others facing similar challenges especially those with similar teaching assignments (Banilower, 2013; Smith, Desimone, & Ueno, 2005). Despite this body of research, there is paucity of empirical studies evaluating the effect of physics-focused professional development on the instructional practice of physics teachers. To fill this gap in literature, this study examined the influence of enhanced in-service physics-focused professional development on AP physics teachers. In examining this phenomenon, the researcher looked at three kinds of outcomes based on Desimone's (2011) framework of effective professional development: 1) did the teachers increase their content knowledge (CK); 2) was there change in classroom practices (PK) and; 3) were there changes in pedagogical content knowledge that led to increase use of reform-oriented practices. The key parts of the chapter include a discussion of 1) research design; 2) population and setting; 3) method of data collection; 4) data analysis techniques, 5) the case study proposition and; 6) summary.

Research Questions

The overarching question for the study was what are the effects of enhanced in-service physics focused professional development on advanced placement physics teachers' instructional practice? The study was guided by the following questions:

1. How does the level of reform-oriented instruction compare in classrooms of advanced placement physics teachers who experienced in-service APEX professional development and those teachers with little or no additional in-service physics focused professional development experiences;
2. How does participating in APEX professional development training affect advanced placement physics teachers' pedagogical content knowledge; and
3. What classroom and school context factors support or impede (mediate) effective implementation of reformed-oriented teaching in AP physics classrooms?

Researcher Positionality

As a science educator for fifteen years, I loved connecting everyday experiences with my students' in-school science experiences. I believe every child can add something new to their science knowledge, but I also struggled with students' apathy toward the learning of science. This created a desire and interest to enhance the teaching and learning of science because students' unfavorable experiences and loss of interest in learning science is often traced to inadequate teacher preparation and lack of effective pedagogy. I strongly believe teachers are the fulcrum for students' learning trajectory and they engender students' interest in any subject. Therefore, my interest is in science teaching and learning, teacher preparation, and effective in-service training that enhances teacher quality. As a graduate research assistant in the last two years, I have been involved with two professional development programs that are NSF and Title

II funded. These programs train high school physics teachers and middle and high school physical science teachers in rural, urban, and suburban schools to enhance their pedagogical content knowledge and improve their students' learning and achievement in science.

Propositions for the Case Study

In a case study, propositions are necessary because it enables the researcher to focus on where to look for relevant evidence to address the phenomenon investigated. It provides focus for the data collection process, direction and scope for the study, and the foundation for a conceptual framework for the research (Miles & Huberman, 1994; Stake, 1995, Yin, 2003). Data generated from this study was linked to the proposition by thematic blocks and relationships between events was established. The study focused on the following propositions: 1) content focused professional development enhances teachers' pedagogical content knowledge which improves classroom instructional practice; 2) higher levels of PCK increases the use of reform oriented instruction; and 3) classroom and school context play a vital role in the effectiveness of teachers.

To understand a case, it was necessary for the case to be bounded within a system (Stake, 1995). This implies that a case exists within some boundaries and its context. The context for this study is bounded around high school physics teachers who are currently teaching at least one AP physics class. The events in a teacher's classroom forms the natural setting for the observation within the context of that school. It is within this context that the unit of analysis which is the case was examined. Miles and Huberman (1994) defined the case as "a phenomenon of some sort occurring in a bounded context" (p. 25). The independent variable is the APEX professional development program and the dependent variable is the AP physics teachers' instructional practice. Because this study is bounded around the AP physics teacher, the questions were framed to address the teacher's instructional practice. This study did not directly measure the effects of professional development on students' achievement because research studies have associated gains in student achievement with reformed instructional practices (Borko, Liston, & Whitcomb, 2007; Grossman & McDonald, 2008). Research also supports the fact that teachers who improve their pedagogical content knowledge use effective instructional practice that leads to higher student achievement (Borko, 2009; Clewell et al., 2004; Darling-Hammond, 1999; Desimone, 2011; Mundry & Boethel, 2005; Ingvarson, Meiers & Beavis, 2005; Peak et al., 2005).

Research Design

This study used an embedded case study design to evaluate the influence of in-service physics-focused professional development on advanced placement physics teachers' instructional practice. Case study is an "empirical inquiry that investigates a contemporary phenomenon in-depth. A case study design is recommended when 'how' and 'what' questions are posed, when the investigator has little control over events within its real life context" (Yin, 2009, p. 18). Creswell (2007) stated that case study is used when an in-depth understanding of a case organized within some boundaries is desired. The case study method allowed the researcher use multiple sources of data for the purpose of triangulation. The triangulation of data was helpful in strengthening the research, producing accurate and reliable data, and providing alternative explanations as well as validity of the processes (Stake, 1995; Yin, 1984, 1994, 2003). The method provided opportunity to use mixed data to capture more information and added richness to the study more than either quantitative or qualitative methods could accomplish on their own (Denzin, 1978; Onwuegbuzie & Collin, 2007; Yin, 2009). Figure 4 illustrates how each strand of the data collection process was constructed, developed, and compared.

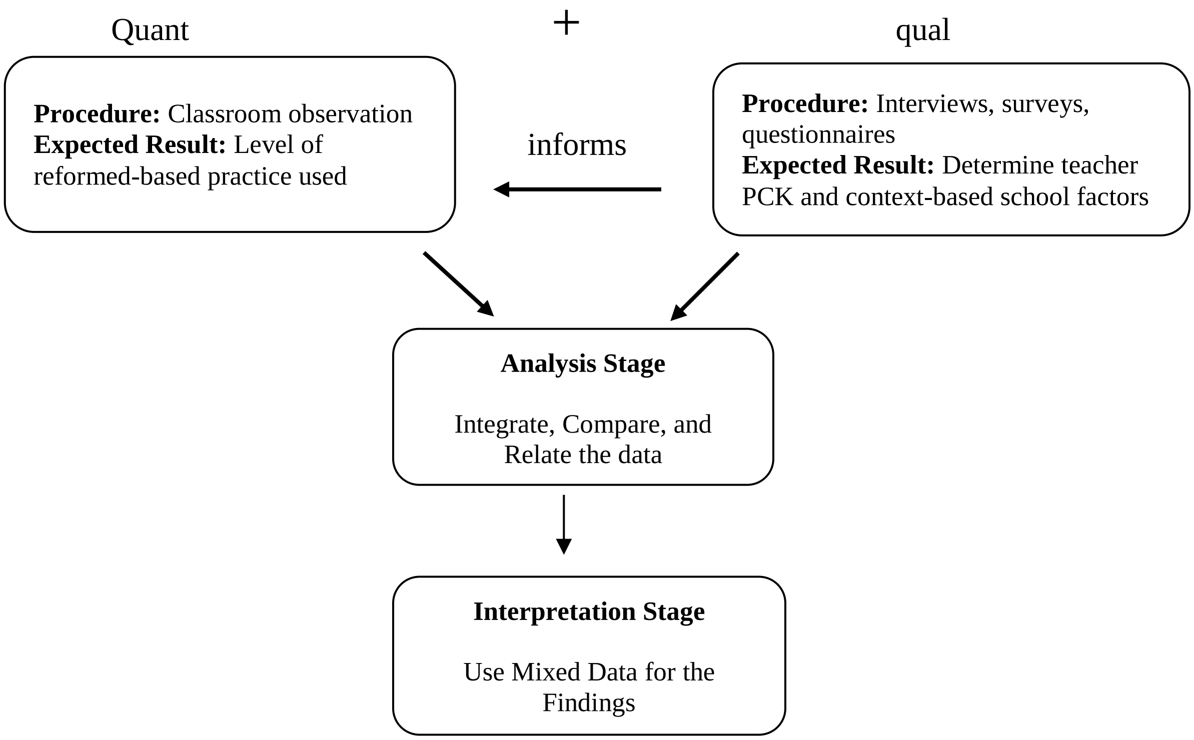


Figure 4. Embedded convergent case study design [Quant + qual]

Population/Setting

Participants in the study were selected from a population of advanced placement physics teachers whose teaching experiences ranged from 2 to 20 years. Participation was open to both genders and all ethnic groups. All fourteen AP physics teachers were purposefully selected from high schools in a southeastern state of the United States because they taught at least one AP physics 1 course at the time of the study. All the participants have experienced the AP College Board training and had participated on some levels in the state science in motion training programs. Of the fourteen teachers selected, seven have experienced additional two years continuous physics focused professional development from the APEX program of over 250 hours. This group represented the intervention group (APD). The other seven participants were selected from the pool of AP physics teachers in the state. This group had little or no additional physics focused professional development. They represented the comparison group (NAPD).

An attempt was made by the researcher to ensure that the comparison group is matched with the intervention group as much as possible. Matching of the two groups may be based on the number of professional development workshops the participants have engaged in and years of teaching. However, to avoid researcher bias, as with every research, there was no assumption in this study that all participants are equivalent in every way.

Instruments

Upon approval from the Institutional Review Board (IRB), the teachers were contacted through letters of invitation, email notification, and person-to-person contact to participate in the study. Once the teachers accepted to be in the study, they were provided all the necessary information and rationale for the study. Prior to classroom visits the surveys and questionnaires were mailed to the teachers or given to them on the first meeting before the classroom observation. Classroom observation was prearranged and conducted on two consecutive days with the same classes of students. Direct classroom observation was used because it was important to provide data that are reliable and that complemented the teacher self-report provided in the surveys and questionnaires. Penuel et al. (2007) stated that “it is important to validate self-reported data on instructional practice against direct observation or some other independent measure of practice” (p. 926).

Primary data was collected by the researcher from classroom observations, surveys, questionnaires, and teacher interviews and secondary data using the same collection protocol was collected by other classroom observers. Observers were trained in the protocol in the same session. The data collected from the comparison group represented their baseline data. Additional post-intervention data was collected from the intervention group. Participants were interviewed after the classroom observations. Interviews were conducted in a quiet and safe environment within the participants' natural setting. The interviews were audio recorded and transcribed verbatim. Participants had the opportunity to review and correct the content of their interview responses and where necessary, they were debriefed to clarify interview responses to ascertain the relevance of the questions to the study objectives. There were also follow-up questions where needed via emails.

Data collection was built around specific observable sets of teacher instructional practices based on the science reform teaching guidelines established by the NSES (NRC, 1996) and the NGSS (NRC, 2013, 2015). Campbell and Smith (2013) stated that alignment of instructional strategies based on the NSES standard "leads to increased student learning when compared with more traditional instructional practices" (p. 163). A test of homogeneity and normality was conducted to compare both groups to ensure there was any no observable difference between the two groups. Comparison of qualitative data in a case study involved analyzing and synthesizing the data to generate themes which were used to identify similarities and differences between the two cases based on their shared common goal. Comparison of the two groups was based on their dependent variables which was the instructional practice observed in their classroom with the aim of identifying similarities or differences between the groups. The independent variable was the physics focused professional development which had occurred at the time of the comparison.

To preserve the anonymity of research participants, pseudonyms and numeric code identifiers were used. All documents and recordings of interviews were kept on a secure passport protected data drive and locked in a filing cabinet that was accessed solely by the researcher. The researcher functioned as a neutral observer and avoided imposing preconceived ideas to illicit participants to say what the researcher may expect. The researcher also kept field notes of all activities during the observation period.

The mixed data was collected from classroom observations, teacher interviews, surveys, and questionnaires. The *Reformed Teaching Observation Protocol* (RTOP) was used to collect quantitative data from *Classroom observation* (see Appendix D). The RTOP is a classroom observational tool introduced by Pilburn et al. (2000) and Sawada et al. (2002) and is based on the science reformed guidelines of the National Science Education Standards. It was used to capture and evaluate the level of reformed practices in the classroom. The researcher completed a training module developed by the authors and conducted practice observations with several observers before the RTOP instrument was used.

The RTOP consists of 25 questions organized into five subscales and each subscale has five statements: 1) lesson design and implementation, 2) content: propositional knowledge, 3) content: procedural knowledge, 4) classroom culture: communicative interactions, and 5) classroom culture: student/teacher relationships. Lesson design and implementation is what the teacher intended to do. This subscale examined how the lesson was designed and implemented by the participants to determine if the process was sufficient to support students' understanding of the lesson. It also examined if the lesson was organized to respect students' prior knowledge and preconceptions and if the teacher was flexible in accommodating students' input and questions, and how this redirected the path of the lesson, and if participants provided opportunities for students to work together in groups or supported the use of learning communities. Soliciting students' prior knowledge helped in identifying and addressing misconceptions (NRC, 2000). Weinstein et al. (2006) noted that creating an active learning experience is a critical factor for motivating student learning.

Propositional pedagogic knowledge is teacher knowledge, organization and presentation of material. This component assessed participants' knowledge of the material. It determined if the lesson was presented in a way that accommodated fundamental physics concepts; if key concepts were incorporated and explored to enable students represent the concepts using different types of abstractions. It also looked at how students' knowledge from other disciplines and real world application were integrated to help them make sense of the new ideas. Jee et al. (2010) noted that using representations to support students' development of abstract concepts promotes student learning of the content.

Procedural pedagogic knowledge is what the students did. The subscale examined what the students did, kinds of instructional activities used to support and engage them; how students used scientific thinking in thought-provoking and problem solving processes, if hands-on activities and lab experiences were tailored toward student conceptual understanding. It also measured the constructive discourse between the students and the teacher leading to students' reflection.

Communicative interactions examined how the participants facilitated interactions among the students. A reformed-based classroom promotes an environment where students actively communicate with one another in a process of explaining their own ideas and evaluating the ideas of others. Student-to-student interactions provide opportunity for them to assess their understanding of the concepts in small and large group settings or whole group discussions.

Student-teacher relationship is a subscale that addresses the culture of respect and comfort as supported by both teacher and learners. It examined if the participants fostered an environment where students' felt comfortable asking questions, if the teacher demonstrated patience, listened to students, and acted as a resource for the students. Weinstein et al. (2006) reported the need for creating a learning environment that supports taking of risks, give students ownership of their learning process and increases their overall learning gains.

The items on the instruments are ranked on a Likert type scale of 0-not observed-to 4-very descriptive. Teacher rating can range from 0 to 100 with higher rating indicating greater level of reform practices in the classroom. Sawada, et al. (2002) stated that RTOP rating between 0 and 100 “allows observers to arrive at a quantitative characterization of the degree to which such reform has been achieved” (p. 251) while an overall RTOP rating of 50 or greater “indicates considerable presence of ‘reformed teaching’ in a lesson” (MacIssac & Falconer, 2002, p. 482).

The RTOP had construct validity that is based on two reform principles: 1) standards-based, and 2) inquiry-based. The instrument has been validated in multiple studies to assess the degree of reformed instruction in science and mathematics classrooms. It provided a precise quantitative reading of the degree to which teaching is reformed (Judson & Sawada, 2001; MacIsaac & Falconer, 2001, 2002; Ogletree, 2007). The RTOP has been validated extensively by multiple research studies and has a reliability rating of 0.954 with sub-scale reliabilities as follows: 1=0.915, 2=0.670, 3=0.946, 4=0.907, 5=0.872 (Piburn & Sawada, 2000). Nix (2012) noted that “classroom teachers demonstrate wide individual differences in content knowledge and pedagogical skills that impact on the learning environment that they create for their students;” (p. 2) therefore, it is necessary to use an instrument that provide such reliability.

Survey data was collected using the *Science Teaching Efficacy and Beliefs* (STEBI-A) (see Appendix F). The instrument was developed by Riggs (1988) and used by Riggs and Enochs (1990) to measure elementary science teacher teaching efficacy and belief in teaching science. Riggs and Enochs reported that beliefs are part of the foundation upon which behaviors are based. The instrument has been extensively validated by the authors and other research studies showing a reliability rating of ($\alpha = 0.92$). The *STEBI-A* was modified and used as

PTEBI-A with the word “science” changed to “physics” to make it more physics specific. Measuring teacher efficacy and belief in teaching AP physics is important to this study because Bandura (1981) stated that “people tend to avoid situations they believe exceed their capabilities, but they undertake and perform with assurance activities they judge themselves capable of handling” (p. 201). Teacher self-efficacy can be enhanced through modeling and successful mastery experiences that comes through continuous training while teacher belief has been widely acknowledged to influence the choices and decisions they make and potentially determine their instructional practice (Lakshmanan et al., 2010).

The Trends in International Mathematics and Science Studies’ (TIMSS, 2015) *AP Teacher Questionnaire* was used for teacher demographics, years of experience, physics content knowledge, and professional development experience. The information provided by this instrument was used in conjunction with the interviews to determine classroom and school context factors that either support or impede effective implementation of reform-oriented practices in the AP physics classrooms.

The *Content Representation* (CoRe) and *Pedagogical and Professional-Experience Repertoires* (PaP-eRs) instruments developed by Loughran, Mulhall, and Berry (2004) were used to structure and record the interview protocol (see Appendix E). The CoRe provided data on participants’ content knowledge and the decision-making process in teaching a particular physics concept observed. The PaP-eRs described the action knowledge displayed by the teacher in teaching the physics concept. Both CoRe and PaP-eRs were modified and used to ascertain participants’ physics pedagogical content knowledge (PCK). Loughran et al. (2006) believe the CoRe and PaP-eRs helps in addressing the “holistic nature and complexity of PCK” (p. 24).

Both instruments provided detailed insights into participants' PCK in teaching AP physics. Additional information were gathered from the teachers' narratives and description of their classroom and school contexts and how they influence the teaching of AP physics. Because all the Loughran et al. instruments have been widely used, their validity and reliability have been established. A descriptive overview of the data collection/instrument is shown in Table 3.

Table 3

Overview of the Evaluation Process

Questions	Research Questions	Variable Examined	Instrument	
			Quantitative	Qualitative
Q1	How does the level of reformed-oriented instruction compare in classrooms of AP physics teachers who experienced in-service APEX professional development (APD) and those teachers with little or no additional in-service professional development experiences?	Level of reform-oriented teaching.	The Reform Teaching Observation Protocol (RTOP) Scores.	
Q2	How does participating in APD training affect AP physics teachers' pedagogical content knowledge (PCK)?	Teacher PCK		CoRe & PaP-eRs PTEBI-A, RTOP
Q3	What classroom and school context factors support or impede (mediate) effective implementation of reformed-oriented teaching in APD and NAPD physics classrooms?	Factors that mediate effective implementation.		CoRe & PaP-eRs PTEBI-A, TIMSS AP Questionnaire

Data Analysis

As a way to triangulate the multiple understanding and establish credibility of findings, this study used different data sources because of the strength it provided for case study research (Yin, 2003). Descriptive and inferential statistical analysis were used for the quantitative data using Statistical Package for Social Sciences software (SPSS) version 24. The descriptive analysis provided the mean and standard deviation used to calculate the effect size. An independent sample *t*-test was also conducted after establishing that the homogeneity and normality assumption was not violated. The *t*-test was used to determine if there was statistically significant difference between the means of the two groups. But due to the small sample size, result from the inferential analysis may only serve as an initial result and a basis for further research with larger sample population. Cohen's effect size (*d*) was used to assess and quantify the magnitude of effect the treatment had on the APD teachers and if there was a difference in between the APD teachers and the NAPD teacher instructional practice. Effect size was calculated by dividing the difference between the means of the two groups by the standard deviation, σ, of the comparison group. Either group's standard deviation can be used because the variances of the two groups was homogeneous (Cohen, 1992; McMillan & Schumacher, 1997).

In analyzing the qualitative data, thematic analysis was used. Merriam (1998) described qualitative data analysis as "the process of making sense out of the data... [which] involves consolidating, reducing, and interpreting what people have said and what the researcher has seen and read – it is the process of making meaning" (p. 178). Thematic analysis was used to inductively code the interview data to establish themes, categories, and relationships. Open coding and axial coding was used to generate the themes. Corbin and Strauss (2008) described coding of items as an interaction with the data "using techniques such as asking questions about the data, making comparisons between the data…deriving concepts to stand for those data, then developing those concepts in terms of their properties and dimensions" (p. 66). Based on these guidelines, the CoRe and PaP-eRs interview responses were transcribed verbatim and analyzed into segments, and then developed thematically from the aggregates of similar codes. Yin (2002) stated that case study analysis consists of "examining, categorizing, tabulating, testing, or otherwise recombining both quantitative and qualitative evidence to address the initial propositions of a study" (p. 109).

The PCK Essential Components rubrics (Ogodo, 2017) developed by the researcher was used to analyze the qualitative data to capture teachers PCK level. The rubric is made up of three components; content knowledge (CK), pedagogical knowledge (PK), and pedagogical content knowledge and each component has 5 items scored on a Likert type scale of 0 to 4. A rating of 0 indicaties the item was missing, 1 = not adequate, 2 = needs improving, 3 = adequate, and 4 = descriptive. The PCK rating was then classified into three levels: 0 – 20 = low PCK; 21 – 40 = medium PCK; and 41 – 60 = high PCK. The lowest possible score of zero means none of the 15 items were observed, and the highest possible score of 60 means all components were evident.

The qualitative data strands was used to the qualitative data as both were integrated to have a holistic understanding of the phenomenon being studied (Creswell, 1998, 2012). Synthesizing the data across the two groups allowed the researcher to compare the similarities and differences. The convergence added strength to the findings as the various data strands were weaved together to promote a greater understanding of the case which was used to support or refute the propositions of the study (Baxter & Jack, 2008).

Construct validity. To establish construct validity, the researcher used instruments and analytic techniques that has been well used and documented with high reliabilities ratings in research studies. The validity of the process used in this study was also guaranteed by the multiple sources of data which provided chains of evidence. The qualitative data collected was used to validate the quantitative data where the study placed more emphasis. There were opportunities provided for member checking with the teachers in the study and triangulation of the various data collected.

Internal validity. Multiple issues were noted that could pose a threat to internal validity of this study. They include the study design, the effect of time; years of teaching experience, teacher level influence, maturation of the comparison group, the effect of intervention from other sources and other alternative explanations that were not considered in this study. These may prevent the study from asserting causality.

Summary

In evaluating the influence of physics focused professional development on AP physics teachers, two main areas were focused on 1) *impact (i.e.* what were the effects of enhanced in-service physics focused professional development on AP teachers' instructional practice); and 2) the *context of teaching* which examined factors that relate to the implementation of effective teaching practices in the AP classroom. These two components enabled the researcher determine if participating in additional physics-focused professional development enhanced the instructional practice of the participants.

CHAPTER IV:

ANALYSIS OF DATA

This chapter will present the analysis of data collected to examine the influence of enhanced in-service physics focused professional development on advanced placement physics teachers' instructional practice. The study used an embedded case study design to collect quantitative and qualitative data from fourteen advanced placement physics teachers. Primary data was collected by the researcher from classroom observations, surveys, questionnaires, and teacher interviews, and secondary data using the same collection protocol was collected by other classroom observers. Observers were trained in the protocol in the same session.

Research Questions

The data analysis was guided by three questions: 1) how does the level of reformed-oriented instruction compare in classrooms of advanced placement (AP) physics teachers who experienced in-service APEX professional development (APD) and those teachers with little or no additional in-service physics focused professional development experiences; 2) how does participating in APEX professional development training affect advanced placement physics teachers' pedagogical content knowledge (PCK); and 3) what classroom and school context factors support or impede (mediate) effective implementation of reformed-oriented teaching in APD and NAPD physics classrooms? Research Question 1 data was quantitatively analyzed using Microsoft Excel and SPSS version 24. Research Questions 2 and 3 data were qualitatively answered from teachers' interviews, survey, and questionnaires. An outline of the method of analysis, variables measured, and instruments used is shown in Table 4.

Table 4

Outline of Method of Analysis

Research Question	Variable Measured	Instrument used	Rating Scale	Method of Analysis
1) How does the level of reform-oriented instruction compare in classrooms of advanced placement physics teachers who experience in-service APEX professional development (APD) and those teachers with little or no additional in-service professional development experiences?	To determine if there are similarities or differences in the type of instruction in both intervention and comparison group.	Reformed Teaching Observational Protocol (RTOP)	0=the behavior never occurred 1= the behavior occurred at least once 2=occurred more than once; very loosely describes the lesson 3=a frequent behavior or fairly descriptive of the lesson 4= pervasive or extremely descriptive of the lesson.	Descriptive analysis Effect Size.
2) How does participating in APEX professional development training affect advanced placement physics teachers' pedagogical content knowledge (PCK) based on their baseline data?	Level of teacher PCK	Teacher Interview Content Representation (*CoRe*) and the Pedagogical and Professional experience Repertoire (*PaP-eRs*) Survey (STEBI – A)		Thematic analysis; open and axial coding. PCK Essential checklist STEBI A instrument 11 items scaled on 5=strongly agree, 4=agree 3=uncertain 2=disagree 1=strongly disagree 12 items analyzed on reversed order.
3) What classroom and school context factors support or impede (mediate) effective implementation of reform oriented teaching in AP physics classrooms?	Factors that mediate/impede effective implementation.	AP Physics Teacher Questionnaire. Teacher Interview.		Thematic analysis: open and axial coding.

Subjects/Setting

All of the fourteen teachers were purposefully selected from a sample population of teachers who are currently teaching AP physics in high schools in a southeastern United States. Teacher characteristics included seven males and seven females with age ranging from 30 to 59 years and teaching experience ranging from one to 20 years. Among the fourteen teachers, thirteen were Caucasians and one was an African American. Teachers were divided into two groups: the seven teachers who attended additional physics focused professional development represented the intervention group (APD) and the seven other teachers who had little or no additional physics focused professional training represented the comparison group (NAPD). All of the teachers have experienced College Board AP training and have been involved in training with the state Science in Motion program. Of the seven teachers in the APD group, only one had completed a physics major and physics teacher certification; others have their major and teacher certification in chemistry, biology, general science and one in engineering. The comparison group is made up of five physics majors, one chemistry, or general science certified teacher. There were two teachers with bachelor's degrees, eleven had master's degrees, and one had a doctoral degree.

All of the teachers currently teach AP physics I courses in urban and suburban public high schools with grades 9 – 12. The student population in the schools observed ranged from 850 to 2,850. The physics classrooms observed were mostly with 11th and 12th grade students. Two classrooms had 10 – 12th grades students and 9 – 12th grade students, respectively. All of the APD group had experienced more than 260 hours of professional development in science-focused workshops, AP physics College Board training, and the physics-focused professional development training from APEX. The NAPD group had five teachers with less than 35 hours of professional development. They had all participated in the College Board training. A snapshot of the individual teachers is shown Table 5.

Table 5

Snapshot of Teachers' Demographics

Variables	Type	*N*	
		APD	NAPD
Gender	Male	3	4
	Female	4	3
Age	30 - 39	3	2
	40 - 49	4	2
	50 - 59	0	3
Degrees	Bachelor's	1	1
	Master's	6	5
	PhD	0	1
Certification	Physics	1	5
	Chemistry	2	1
	Biology	1	
	General Science /math/Engineering	3	1
Science teaching experience	1 – 7	3	2
	8 – 14	2	1
	Over 15	2	4
AP teaching experience	1 - 7	6	1
	8 - 14	6	1
Average student population		1,430	1,700
Hours of PD	Less than 35	0	5
	More than 35	7	2

The classroom observations were carried out in the teachers' natural classroom setting, and they chose the lessons that were observed. This was to ensure that the teachers were familiar and comfortable with the lesson that was observed. Descriptive statistics comparing the two groups of teachers is shown in Table 6.

Table 6

Comparison of APD and NAPD Teachers' Experience

Variable		*N*	*M*	*SD*	*t*	*p*
Teaching Experience	APD	7	5.2857	6.34710	.550	.592
	NAPD	7	4.2857	10.02378		
AP Teaching Experience	APD	7	11.4286	3.54562	-.605	.556
	NAPD	7	14.1429	3.25137		

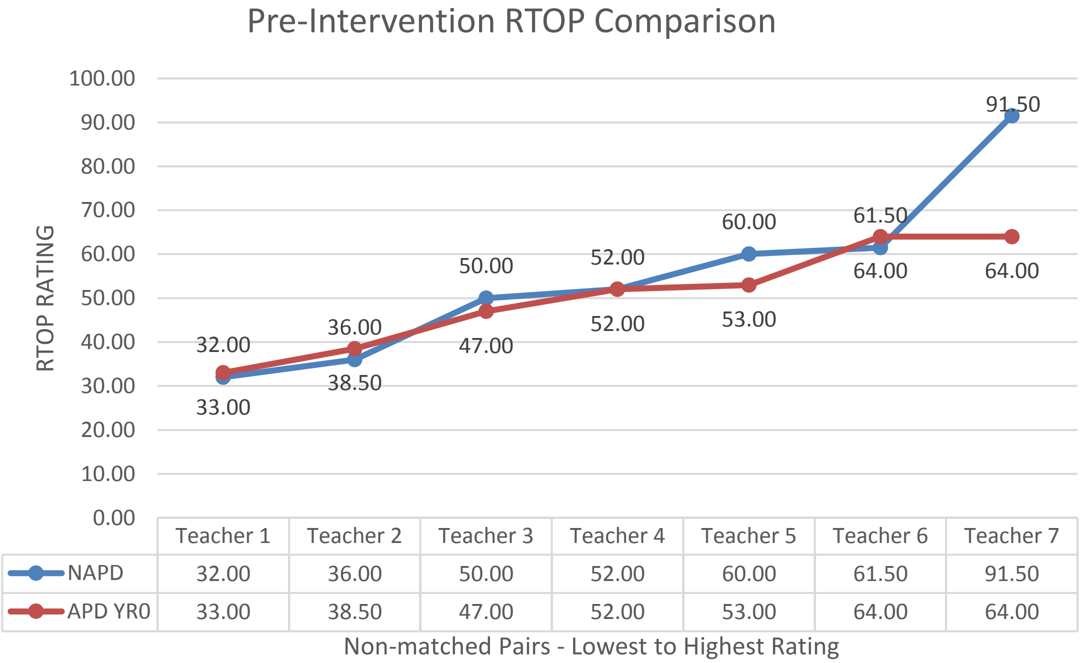
M = mean, *SD* = standard deviation

The result showed that there was no significant difference between the mean teaching experience of the APD (M = 5.29, SD = 6.35), and NAPD teachers (M = 4.29, SD = 10.0); t(12) = .55, p =.59. There was also no significant difference between the teachers mean AP teaching experience (M =11.4, SD = 3.55) for the APD teachers and (M = 14.1, SD = 3.25) for the NAPD teachers; t(12) = .61, p = .56. The mean of the two groups are the same across the categories of teachers.

Research Question One (RQ1)

How does the level of reformed-oriented instruction compare in classrooms of advanced placement physics teachers who experienced in-service APEX professional development (APD) and those teachers with little or no additional in-service physics focused professional development experiences NAPD? To respond to RQ1, the data was analyzed using descriptive and inferential analysis. The teachers' classrooms were observed on two consecutive days using the *Reformed Teaching Observational Protocol* (RTOP) instrument to measure the level of reformed instruction based on the instrument five subscales. The total overall RTOP rating ranged from 0 to 100 with higher rating indicating greater level of reform practices.

Classrooms' RTOP ratings from the two visits were combined to obtain an average score for each teacher. An overall rating of 50 or greater "indicates some presence of 'reformed teaching' in a lesson" (MacIssac & Falconer, 2002, p. 482). A rating of below 50 indicates more traditional lecture-based teaching while a score of 80 indicates a student oriented inquiry lesson. The average rating for the APD group pre-intervention was 50.2 and 54.7 for the NAPD group. An average rating of above 50 means that there were evidence of some level of reformed-based instruction in the classrooms of some of the teachers prior to the intervention. The pre-intervention APD rating and NAPD data for the teachers are shown in Figure 5.



	Teacher 1	Teacher 2	Teacher 3	Teacher 4	Teacher 5	Teacher 6	Teacher 7
● NAPD	32.00	36.00	50.00	52.00	60.00	61.50	91.50
● APD YR0	33.00	38.50	47.00	52.00	53.00	64.00	64.00

Figure 5. Pre-intervention APD and NAPD baseline rating

A test of normality and assumptions of homogeneity of variance was conducted to ensure the two groups are reasonably equivalent before the additional training. Lavene's *F* test *F* = (12)

=.796, *p* = .390. This result indicated that there was no differences in variance between the pre-intervention APD and NAPD teachers; normality and assumptions of homogeneity of variance were not violated.

After the intervention, the APD teachers were rated higher than the NAPD teachers. The mean rating for the APD teachers increased from 50.2 to 77.1. This means that the APD teachers implemented more reformed based instruction after the intervention. Figure 6 shows a comparison of the post-intervention APD teachers' rating and the NAPD rating.

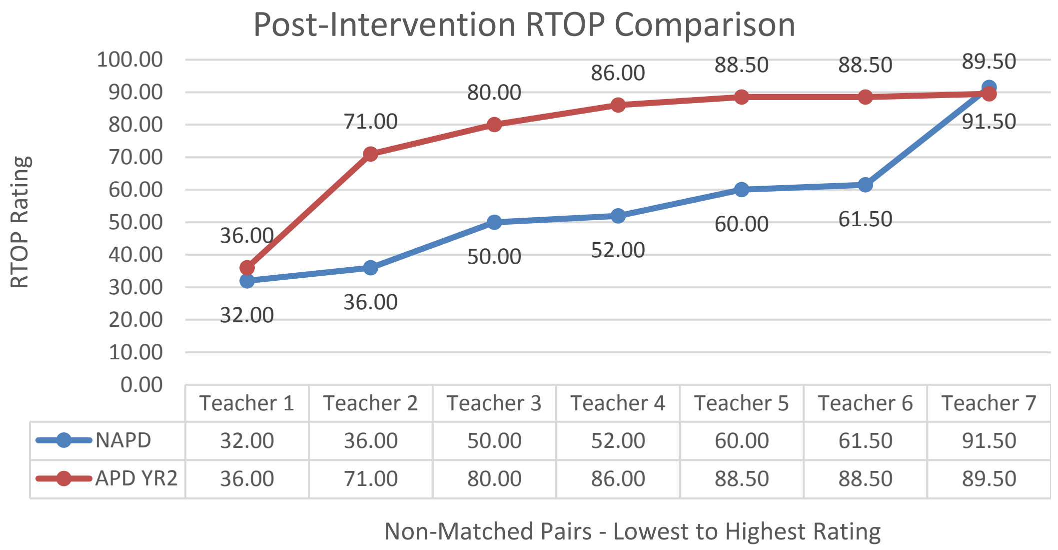


Figure 6. Post-intervention APD and NAPD rating

Teacher NAPD02 had the highest rating of 91.5, which was considered an outlier because it lies an abnormal distance from the other values within that group. Teacher APD06 had the lowest post-intervention rating of 36. A negative 11 points difference from the pre-intervention rating of 53. The data showed that six of the seven APD teachers implemented more reformed-based practices in their classrooms and used less teacher-centered instructions compared to the NAPD teachers' average rating.

The post-intervention APD subscale rating were compared with the NAPD subscale ratings. The RTOP subscales assessed were 1) Lesson Design and Implementation (LDI); 2) Propositional Pedagogic knowledge (Prop-PK); 3) Procedural Pedagogic Knowledge (Proc-PK); 4) Communicative Interactions – (Comm-I); and 5) Student-Teacher Relationship (STR). The subscale data is shown in Table 7.

Table 7

APD and NAPD Teachers RTOP Subscale Rating

		Total Subscale Rating							
Subscale	Group	1	2	3	4	5	6	7	Mean Rating
LDI	NAPD	6.00	18.00	5.50	8.00	11.50	11.50	2.50	12.60
	APD YR 2	17.00	18.50	14.50	15.00	4.00	17.50	21.00	21.00
PROP-PK	NAPD	14.00	18.50	14.50	15.00	15.00	16.50	11.50	21.00
	APD YR 2	18.50	18.50	18.50	14.50	17.00	12.50	18.50	23.60
PROC-PK	NAPD	11.00	18.00	3.50	8.50	8.00	4.00	4.50	11.50
	APD YR 2	15.50	15.00	15.00	12.50	13.50	5.00	18.00	19.00
Comm-I	NAPD	14.00	17.50	5.00	9.50	9.50	8.50	4.50	13.70
	APD YR 2	16.00	17.00	17.00	12.00	15.50	6.50	17.00	20.20
STR	NAPD	16.50	19.50	7.50	9.00	16.00	11.50	9.50	17.90
	APD YR 2	19.00	19.50	19.50	18.00	19.00	8.00	18.00	24.20
Overall Rating	NAPD	61.50	91.50	36.00	50.00	60.00	52.00	32.50	54.74
	APD YR 2	86.00	88.50	88.50	71.50	80.00	36.00	89.50	77.14

An independent *t*-test was conducted to examine if there was a statistically significant difference between the means of the two groups based on the subscales data. The result, $t(12) =.32$, $p = .008$, indicates that the APD teachers' mean ratings were significantly larger than the NAPD teachers. Effect size was also calculated due to the small sample size to assess and quantify the magnitude of effect the APD training had on the teachers. The result showed an overall subscale rating of APD ($M = 77.14$, $SD = 19.24$; $d = 1.15$), NAPD ($M = 54.78$, $SD=19.58$). A large effect size difference of $d =1.15$ was found between the groups based on Cohen's guidelines (Cohen, 1988, 1992; Field, 2009). Cohen (1988) defined effect size as small, *d* = .2, medium, *d* = .5, and large, *d* = .8. Effect size can range from -3.0 to 3.0 on the Cohen's *d* scale. The assessment of each subscale is discussed below.

Lesson Design and Implementation (LDI)

The teachers were rated based on how the lesson was organized. This included lesson implementation that respected students' prior knowledge and pre-conceptions and if the lesson created opportunity for students to work together in small groups. There was a large effect size difference between the APD (*M* = 15.0, *SD* = 5.10; *d* = 1.17) and the NAPD (*M* = 9.00, *SD*=5.13) group. The APD teachers used activities that respected students' prior knowledge. Six of the seven APD classrooms had small group settings. Students worked in groups of threes, fours, and sometimes five depending on the class size. The NAPD group had three classrooms set up with small groups and four classrooms that were more traditional with students facing the board/instructor.

Propositional Pedagogic Knowledge (Prop-PK)

This subscale assessed teachers' knowledge of the material and how they incorporated fundamental concepts of the lesson to enable the learner to demonstrate their understanding using elements of abstraction. A large effect size difference of APD (*M* = 16.86, *SD* = 2.43; *d* = 0.81) and NAPD (*M* = 15.00, *SD*=2.16) was observed in this subscale. This means the APD teachers were using more pedagogical strategies that enabled the learner to objectify abstract concepts in a manner that enhanced their conceptual understanding than the NAPD teachers.

Procedural Pedagogic Knowledge (Proc-PK)

Proc-PK focuses on what the student did. It assessed how the instructional activities supported and engaged the learner and how the classroom discourse between the learners and teacher led to students' reflection. The effect size difference was large between the APD = (*M* =

13.57, *SD* = 4.21; *d* = 1.37) and NAPD (*M* = 8.21, *SD* =5.12) data. The major difference observed between the APD and NAPD classrooms was that scientific processes such as lab activities were used as a confirmatory exercise after a lecture in five of the NAPD classrooms, which was unlike the APD classrooms where five of the classrooms provided the learner the opportunity to explore before formal introduction of the concept. In addition, the APD students were reflective of their learning as they solved problems together and presented their work in groups or on a whiteboard. They discovered scientific terms for themselves through group inquiry.

Communicative Interactions – (Comm-I)

This subscale rated the teachers on how they facilitated interactions among the students. A large effect size difference between the APD (*M* = 14.43, *SD* = 3.92; *d* = 1.08) and the NAPD (*M* = 9.78, *SD*=4.65) was observed. Because five of the NAPD classrooms were set up in the lecture-type format, there were limited interactions between the students; they mostly took notes or responded to the teachers' questions. However, in the APD classrooms, the teachers provided the latitude for group activities, exploration, and discussions that engaged the learners while the teacher guided and facilitated the process.

Student-Teacher Relationship (STR)

This subscale assessed if the environment fostered respect and comfort for both teacher and learner. STR rated if the teacher demonstrated patience, listened, and acted as a resource for the students. The effect size difference was large between the groups: APD = (*M* = 17.29, *SD* = 4.14; *d* = 1.03), NAPD (*M* = 12.79, *SD*=4.54). The environment of respect was more evident in the APD because of the collaborative group settings. There were more student interactions; they had the freedom to express their thoughts, ask questions, and have argumentative discussions. The APD and NAPD teacher effect size is shown in Table 8.

Table 8

Effect Size for Post Intervention APD and NAPD Teachers (N=7)

Subscale	Group	Mean	Std. Deviation	Minimum	Maximum	ES (*d*)
LDI	NAPD	9.0000	5.13160	11.50	24.50	
	APD YR 2	15.0000	5.09902	17.50	28.00	1.17
PROP-PK	NAPD	15.0000	2.16025	8.00	19.00	
	APD YR 2	16.8571	2.42752	18.00	24.50	0.81
PROC-PK	NAPD	8.2143	5.12231	10.00	25.50	
	APD YR 2	13.5714	4.21731	17.50	27.00	1.37
Comm-I	NAPD	9.7857	4.65347	13.00	20.00	
	APD YR 2	14.4286	3.92034	18.00	24.00	1.08
STR	NAPD	12.7857	4.54475	11.50	23.00	
	APD YR 2	17.2857	4.14183	16.00	25.00	1.03
Total Rating	NAPD	54.7857	19.58072	57.50	105.00	
	APD YR 2	77.1429	19.24343	95.00	121.00	1.15

Summary for Research Question One (RQ1)

RQ1 compared the level of reformed-based instruction in classrooms of AP physics teachers who experienced APD training with those teachers with little or no additional in-service physics focused professional development experiences. The result from the RTOP ratings showed that the APD teachers implemented more reformed-based instruction in their classrooms than the NAPD teachers. A large effect size difference showed that the APD teachers used instructional strategies that are more student-centered and less teacher-centered. Although the NAPD teachers had five out of seven teachers with physics degrees, they were not translating the content knowledge effectively with reformed-based instruction. Most lacked adequate pedagogical skills needed to transform what physics content they knew into meaningful learning experiences for the learners.

Research Question Two (RQ2)

How does participating in APEX professional development training affect advanced placement physics teachers' pedagogical content knowledge (PCK)? This question was addressed qualitatively using APD teachers' interviews, RTOP, surveys, and the researcher notes. A PCK rubric was developed based on Loughran et al, Shulman's PCK and other essential components of PCK from the literature (Ogodo, 2017). The APD teachers reported growth in their content knowledge and changes in their pedagogical practices which they attributed to the APEX training. The PCK Essential Component Chart is shown in table 4.

Interview

The CoRe and PaP-eRs interview protocols were used to access teachers' knowledge on how they conceptualize and make decisions in teaching specific AP physics concepts. The CoRes was used to explore the teachers' knowledge of the specific concept observed while the PaP-eRs captured the teachers' pedagogic knowledge in practice. Combining the CoRe and PaP-eRs enabled the researcher to evaluate and document the teachers' progress and to validate instances of PCK as they occurred (Bertman & Loughran, 2012).

Teachers were asked questions such as 1) what are your goals in teaching advanced placement physics to your students this year; 2) what typical teaching method do you use to do this; 3) has the way you teach physics changed overtime; and 4) what typical teaching procedures will you use to engage students with this ideas? The interview responses and the researcher' notes were used to prepare the narrative on the pedagogical and professional experience repertoire (PaP-eRs). PaP-eRs highlights "a particular piece, or aspect, of science content" that was observed being taught (Loughran et al., 2006, p. 24). The CoRe and PaP-eRs recorded at different time periods, pre and post-intervention, were used to determine if there were changes in teachers PCK during the period of training.

Survey Instrument

In addition to the CoRe and PaP-eRs, a survey of teachers' self-efficacy and belief was completed by the teachers. The *Physics Teaching Efficacy and Belief Instrument* (PTEBI) survey was used to examine teachers' self-efficacy and beliefs about teaching physics in high school. The 23 items on the survey were rated from 23 to 65 with thirteen items reverse coded. The survey items are based on two subscales; the personal physics teaching efficacy (PPTE) which measured teacher's belief in their ability to teach physics and the physics teaching outcome expectancy (PTOE) which assessed teachers' belief that student learning can be influenced by effective teaching. The ratings were analyzed to understand how the teachers perceived their ability to implement the lesson and how well they responded to students' questions. The pre- and post-intervention data is shown in Table 9.

Table 9

Pre- and Post-Intervention APD PTEBI Rating

Teachers	PPTE (13 – 65)		PTOE (10 – 50)		Total score (23 – 115)	
	YR 0	YR 2	YR 0	YR 2	YR 0	YR 2
APD01	42	18	34	24	76	42
APD02	37	23	27	25	64	48
APD03	37	17	28	24	65	41
APD04	34	28	25	23	59	51
APD05	38	21	26	23	64	44
APD06	37	27	25	27	62	54
APD07	40	20	23	22	63	42
Mean Score	38	22	27	24	65	46

The data showed an interesting result. The teachers' pre-intervention self-rating was higher for the personal physics teaching efficacy subscale than the post-intervention rating. The physics teaching outcome expectancy remained almost the same with higher margins in the pre-intervention rating. A paired t-test analysis of the survey data showed a significant difference between the pre-intervention self-efficacy (PPTE) subscale (M = 37.9, SD = 2.54) and post-intervention PPTE subscale (M = 22.0, SD = 4.24); t(6) = 6.7, p = .001). There was no significant difference observed in the PTOE observation expectancy subscale (M = 26.9, SD = 3.53) and post-intervention PPTE subscale (M = 24.0, SD = 2.87); t(6) = -1.5, p = .084). However, there was a significant difference overall between the pre-intervention teacher self-efficacy and belief and the post-intervention score (M =46.0, SD = 5.35) and post-intervention score (M = 64.7, SD = 5.07); t(6) = 5.4 , p = .002). The paired t-test analysis of the PTEBI rating is shown in table 10.

Table 10

PTEBI Paired t-test Analysis

Variable		*n*	M	*SD*	*t*	*p*
Pair 1	PPTEYR0	7	37.8571	2.54484		
	PPTEYR2		22.0000	4.24264	6.677	.001
Pair 2	PTOEYR0	7	26.8571	3.53217		
	PTOEYR2		24.0000	2.874	-1.544	.084
Pair 2	Total score YR0	7	46.0000	5.34522		
	Total score YR2		64.7143	5.06623	5.395	.002

M = Mean, *SD* = Standard Deviation, p = .05

This finding supports Powell-Moman and Brown-Schild's (2011) study in which teachers judged their self-efficacy based on their pedagogical knowledge, but after they received training, they judged themselves based on the increased content knowledge and pedagogical knowledge.

Earlier studies have found that teachers who apply new knowledge or ideas from professional development programs show higher levels of self-efficacy (Ross & Bruce, 2007), and that content knowledge and pedagogical knowledge component of professional development leads to higher levels of teacher self-efficacy (Swars & Dooley, 2010). Effective professional development changes teacher knowledge and alters their beliefs (Desimone, 2011).

Based on the teachers' interview responses, two plausible explanations can be inferred for the lower post-intervention rating: 1) there was a paradigm shift; or 2) teachers had self-doubt of long-held ideas and definitions of teaching and learning. The APD teachers' new knowledge challenged their existing self-efficacy as they discovered how much they did not know and scored themselves lower. Teacher APDO1 stated, "the program has helped me to draw better connections between different areas of physics." Teacher APD06 noted that

> APEX has definitely provided me with deeper content knowledge that I use daily in my lessons. I now have a better understanding of the underlying concepts and the 'how' rather than just the factual 'what', it has also allowed me to better explain some of general processes.

Teacher APD06 believed that "notes and problems solving technique worked well for his colleague for past 20 years" and that was why he used the same method. His post-intervention response stated that "I do more labs now because of APEX, I try to challenge the students more to draw out of them what they have learned, so they have practical experiences." Teacher APD01 stated, "I changed because I went to multiple training that showed the benefit of that method, those types of methods. Lab–based, inquiry methods."

Although the teachers' pre-intervention PPTE self-ratings were high, the classroom observation ratings were low. This agrees with Nepor (1989); he reported that when determining classroom actions, teachers often rely on their core belief systems that is personal and context-based. He also observed that although the teachers in this study scored high on the STEBI survey, their classroom observation rating were low. He concluded that teachers believed they were using reformed teaching behaviors and teaching effectively.

A similar national study was conducted by Lardy and Mason (2011) to examine the impact of reformed undergraduate science courses developed through the NOVA program on elementary teachers' science teaching self-efficacy beliefs. They observed 85 in-service teachers during their first few years of teaching using the RTOP observational protocol used to assess the teachers' levels of reformed teaching and the STEBI-A efficacy and belief instrument and found no correlation between the teachers' observed teaching and their self-efficacy ratings.

Thematic Analysis of the Interviews

The transcribed interview, survey data, and researcher's notes were used to construct the CoRe and PaP-eRs. Open coding and axial coding were used to identify the items, sort them into categories, and develop them into themes. The CoRe interview was divided into two sets of questions: content/pedagogy and school context. The content/pedagogy themes were used to respond to RQ2. Open coding yielded seven categories: a) teachers' teaching methods; b) best way to teach physics; c) changes in teaching method; d) knowledge and skills needed to teach; e) confidence in teaching; f) knowledge about how students think or learn; and g) how to determine students' understanding and confusion. These categories were coded further using axial coding and four themes emerged including 1) teacher knowledge, 2) teaching practice, 3) teacher belief, and 4) teacher persuasion. The themes helped in identifying the teacher PCK and the changes that occurred because of the intervention.

Teacher knowledge. Teaching physics requires adequate knowledge of the content. APD teachers' responses revealed that their subject matter knowledge and teaching experience influenced how they implemented the lesson. A grounded subject matter knowledge is needed to ask the right questions and to connect the concepts with other ideas in a way that promote student's understanding (Anderson & Freebody, 2012; Findel, 2009). Teachers noted that experience from teaching the course, constant renewal by staying ahead of the learner, and most importantly, knowledge from the training has helped in developing the skills needed to be effective in the classroom. Post-intervention, the APD teachers reported that

> APD03: Before APEX, I will introduce an equation and explain where it came from, but now the students basically discover the relationships before the names and use that relationship to solve problems,
>
> APD05: The training from APEX have helped in preparing me with the skills and strategies to teach the course, and
>
> APD04: I am learning more than what I learned in college from the APEX training.

As the APD teachers became more comfortable with the lessons, they used more student-centered activities based on the new information and knowledge.

Teaching practice. Teachers' pre-intervention responses showed that they used more teacher-centered teaching methods such as lecture, problem-solving, notes, teacher demos, and cookbook-type lab activities. They were more focused on preparing students to pass the AP exams. They stated the following:

> APD01: I am preparing them for AP exams, I'm focused on teaching the content, so I use more lecture;
>
> ADP06: I use notes with problem solving and direct presentations; and
>
> ADP02: I use lecture and problem solving, I try not to use straight lecture, it depends on the nature of the concept.

Teachers' responses changed after the training to including the following:

> APD01: I use mostly lab or inquiry based teaching;
>
> ADP06: I do some labs, and I do more labs now because of APEX; and

> ADP02: Before APEX, I will do lecture, then lab, and then talk about the result, now the kids do the investigation, which is awesome.

The teachers began to integrate more reformed-oriented practices in the lessons as they moved away for teacher-based practice. Their new strategies gave student ownership of the learning process. Teacher APD04 noted that

> Knowing the content alone was not enough for me, I needed the pedagogy of how to teach the content to my students. My math background was not solid but with PD opportunities and APEX, I am learning more than I did in college.

Teacher beliefs. Teacher beliefs played a key role in the instructional choices the APD teachers made. Pre-intervention data showed that they preferred the traditional lecture method because it required less planning, it was easier and more in their comfort zone, and because that was how they were taught as students. It became their default mode. Some claimed it was used because it simply works. Teacher APD07 believes that using mostly lecture, notes, homework, and doing some labs enables her to cover the AP materials faster than the time-consuming, reformed-based strategies. During post-intervention, there were shifts observed toward more inquiry and hands-on activities, the use of collaborative learning groups, and a focus on students' conceptual understanding and not just on their AP scores. Teacher APD06 stated, "Well obviously, I want them to pass the AP physics exam, but along the way I want them to have a really good understanding of physics, the fundamentals of the actual concepts." Teacher APD02 now believes that "inquiry-based is the best way to teach because students are more engaged and usually retain better if they find the answer on their own, rather than being told." There was an observable shift from traditional lecture as students were given ownership of their learning process.

Teacher persuasion. Persuasion is used here to describe factors such as *teacher experience* or *teacher confidence* that influence the effectiveness in teaching. Confidence often comes from having the content knowledge or from having the teaching experience over a period of time. Of the seven APD teachers, only one had a degree in physics and he was the most comfortable in teaching the subject. He (ADP01) stated, "I have the physics background, so I feel like I do a pretty good job on that end because I know the content." The teacher with an engineering degree also exhibited confidence in teaching the concept; however, she noted, "I took every physics class but I still didn't get a deep understanding of the physical world until I learned it with this APEX modelling method." Others stated that their teaching experience over time helped in making them more comfortable with some of the concepts. Teacher APD05 stated, "I feel pretty confident because of the few years I have under my belt of teaching AP class." Teacher APD07 stated that "when I first started teaching I was doing hands-on activities anyways all the time, so that's probably how I've always taught."

But having the content knowledge or experience did not always translate into effective classroom practice. Upon pre-intervention, Teacher APD04 stated that she lacked the confidence because she was not certified to teach physics: "I needed the conceptual understanding of the concepts." However, post-intervention, she stated, "Umm, I think you need more than just the content, you do need to know the content, but then you need the pedagogy of how to teach the content to the students." Those teaching out-of-field struggled with more difficult concepts such as electricity, magnetism, waves, sound, light, etc. Teacher APD02 stated, "I don't feel as confident in teaching those because it's difficult to teach and it's difficult to understand, I was learning the material as I was teaching it, but I'm a lot more comfortable teaching it now." This lack of confidence limited them to methods that they were not comfortable with, which gave them reason to default to lectures, problem solving, teacher demo, etc. and avoidance of instructional practices that they were not familiar with or perceived as "time consuming." But after the training, as their physics teaching experience increased and content knowledge improved, their self-efficacy increased in using reformed-oriented instruction.

Capturing Teachers' PCK

The complexity of capturing and portraying the PCK construct has been well documented in literature. To unpack the teachers' PCK, it was necessary to relate it to the goals and objectives of the model professional development program providing the training. The primary objective of the APEX professional development program was to enable in-service physics teachers to acquire a deeper content knowledge of physics and to employ effective research-based pedagogical strategies in the classrooms, thereby improving their PCK. The teachers' PCK were captured using the PCK essential component rubrics (Ogodo, 2017) based on insights from Shulman PCK (1986, 1987), Loughran et al. (2006) CoRe interview instrument, and researched literature on content knowledge (CK), pedagogical knowledge (PK), and pedagogical content knowledge (PCK). See previous Chapter 3 for a more detailed description of PCK measurement. This enabled the research to capture the teachers' pre- and post-intervention PCK and also identify the changes that occurred as a result of the APD training. The PCK Essential Components Rubric is shown in Table 2.

Each item on the PCK Essential Components Rubric was scored on a Likert type scale of 0 to 4 with 0 indicating the item was missing, 1 = not adequate, 2 = needs improving, 3 = adequate, and 4 = descriptive. A teacher's score could range from the lowest possible score of 0 meaning none of the 15 items were observed to 60 the highest possible score. The rating was divided into three levels: rating of 0 – 20 = low PCK; 21 – 40 = medium PCK; and 41 – 60 =

high PCK. In addition to the CoRe and PaP-eRs, their RTOP ratings provided additional information and was noted with the asterisk. Based on these criteria, the teachers were rated as low, medium, and high PCK. The teachers’ PCK rating is shown in Table 11.

Table 11

APD Teachers Pre- and Post-Intervention PCK Rating

Categories	#01 James		#2 Charles		#03 Emily		#04 Jennifer		#05 Michael		#06 Ethan		#07 Sue	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
CK														
1. Solid Content knowledge. *8	4	4	1	3	4	4	2	3	2	3	1	3	2	3
2. Use of Questions/Prior knowledge. *1	1	4	3	4	3	4	1	3	2	3	0	2	2	3
3. Connection to other ideas and real life. *10	3	3	4	3	1	3	1	2	3	3	0	2	2	3
4. Repertoire of teaching.	1	4	1	4	2	4	1	3	1	3	1	2	2	3
5. Innovative materials for teaching.	1	4	1	3	2	4	1	3	1	3	1	2	3	3
PK														
1. Transforms content knowledge to effective teaching.*5	1	4	1	4	3	4	2	3	1	3	1	2	2	3
2. Students' thinking and learning.	3	4	2	3	3	4	1	3	2	3	2	2	2	3
3. Knowledge of effective classroom assessment.	2	4	2	4	3	4	2	3	2	3	1	2	1	3
4. Activities address student needs or demands.	1	4	1	4	2	4	1	3	2	3	1	2	3	3
5. Internal or external factors that influence classroom instruction.	2	3	2	3	3	4	1	3	1	3	1	2	2	3
PCK														
1. Blends content and pedagogical knowledge	1	4	0	3	2	4	2	4	1	3	0	2	3	3
2. Displays confidence as a content specialist	4	4	1	3	4	4	2	3	2	3	1	3	3	3
3. Uses effective assessment	1	4	1	3	3	4	1	3	1	3	1	3	3	3
4. Instruction is students directed *19	0	3	2	3	2	3	1	3	1	3	0	2	2	2
5. Effect of professional development	1	4	0	3	2	4	1	4	2	4	0	2	2	3
Total	26	57	22	50	39	58	20	46	24	46	11	33	34	44

Comparing Teachers' PCK Levels

The result showed five teachers who had medium level PCK and two who had low level PCK before the intervention. During post-intervention, four teachers moved up one level from low PCK to high PCK while one remained within the same PCK range.

Teacher APD01. Pre-intervention, James was more focused on prepping his students for the AP exams. Because he followed the College Board pacing guide strictly, he used mostly lecture and problem-solving techniques. He said, "It's an AP class. It's teaching the content – we're trying to prepare them to take the AP exams." Although he acknowledged that his physics content knowledge helped in navigating through the concepts, he struggled with ways of engaging all of his students: "knowing how to engage all the students especially in a diverse class setting." He was unable to translate his content knowledge into effective pedagogical practice. His pre-intervention PCK rating was 26, or medium-level PCK. Post-intervention data showed that while James was still focused on prepping his students for the AP exams; he used more reformed-based activities to achieve this goal. He stated, "I'm less problem driven, I want them to take data and be able to describe what is going on, I use mostly labs and inquiry based teaching because it engages students more." His post intervention PCK rating increased from 26 to 57, high level PCK.

Teacher APD02. Before APD training, Charles stated that he tried not to lecture the entire time. Sometimes he lectured for 20 to 30 minutes but engaged more in AP problem solving. He explained, "it was easy to fall back to lecture and worksheets because it is easier and most comfortable." He struggled with teaching physics because he does not have a physics degree and lacked the confidence to teach inquiry-based lessons because he did not know how. He often used prescribed and "cookbook type" labs. His pre-intervention PCK score was 22, or low medium level. Post-intervention, Charles stated, “Before APEX, I will do lecture, then do a lab, and then talk about the result. It was more of me force-feeding the stuff to the kids, rather than the kids doing an investigation.” His new confidence changed his self-efficacy. He stated, “I am no longer struggling to convey everything, now I let them discover on their own, that’s what the APEX program has helped me to achieve, I am pretty confident.” His PCK level increased from 22 to 50, high level PCK.

Teacher APD03. Prior to the APD training, Emily believed that “inquiry and student-centered activities” are the best way to teach physics and that “research show[s] such approaches yield greater gains in conceptual learning.” Although she was not a physics major, she had enough physics background/training to use student-centered activities in her classroom. Her pre-intervention rating was 39, or medium level PCK. Post-intervention, she stated, “before doing APEX I might introduce an equation, and talk about where it came from, now they (*students*) are frontloaded with discovery labs, they discover the relationship before the names and use that relationship to solve problems.” She credited APEX for the deep understanding she now has for the physical world. Her PCK rating increase from 39 to 58, high level.

Teacher APD04. Pre-intervention data for Jennifer showed that she wanted the conceptual understanding of physics which was not her field. She explained, “I want to know the content and the different strategies for physics teaching…the hands-on experience to reinforce the students’ knowledge.” Her inadequate physics knowledge left her using “more lecture because it is more comfortable and requires less planning.” Her pre-intervention PCK rating was 20, or low level. After the training, she stated that “knowing the content alone is not enough, there is need for the pedagogy, how to teach the content to the students.” She also noted that her “math background was not solid when [she] first started teaching but with more PD opportunities and now APEX, [she was] learning more than what [she] learned in college." As a result, her pedagogy changed. She stated, "my approach toward labs has changed, because it's no more cookie cutter, it's more hands-on because they get to experience and see for themselves." As Jennifer added to her teaching repertoire, she became more confident in implementing reform-based practices. Her PCK rating increased from 20 to 46, high level.

Teacher APD05. Pre-intervention, Michael's first year teaching was "here's the formulas, here's what we plug in and here's how we find this or that." He has made progress since then "we do interactive lecture, working problems in collaborative groups." He believed the method was "pretty effective and it helped to relate concepts to students' experience." His pre-intervention PCK was 24, or medium level. Post-intervention, Michael stated, "the APEX training has helped in preparing me with the skills and strategies to teach the course, I use questioning to keep them engaged and to identify their own misconceptions." He now uses "a combination of strategies that include open inquiry, Diagnoser, White-boarding, and more Socratic questioning." His PCK rating increased from 24 to 46, high level.

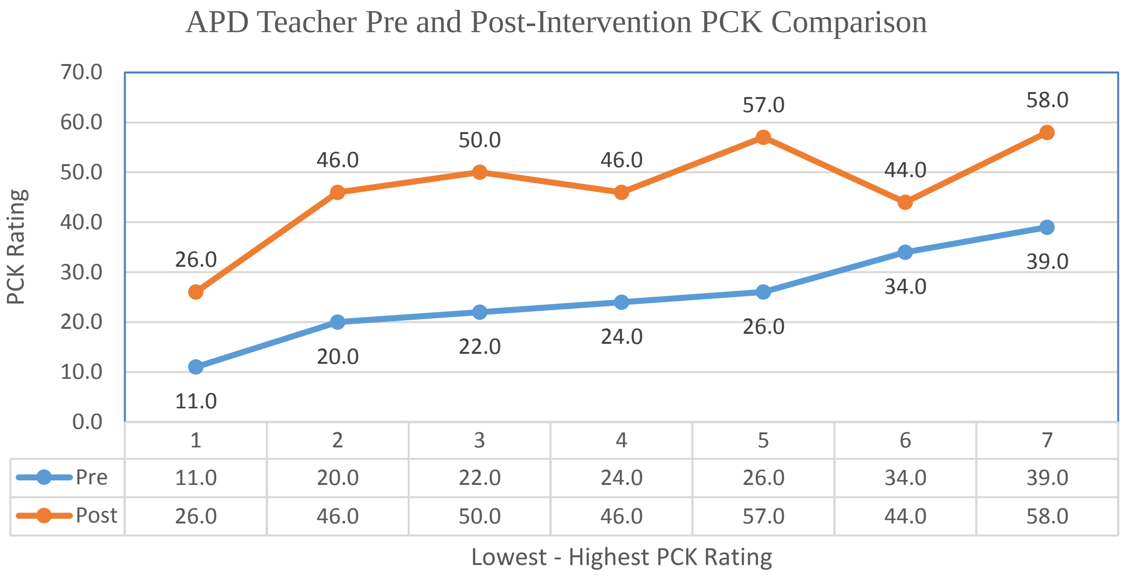
Teacher APD06. Ethan had no physics background; he learned the content from teaching: "I decided to learn the material as I was teaching it, but I'm a lot more comfortable teaching it now because of experience." Pre-intervention, he noted that his math skills helped in teaching physics, but he preferred using direct instruction, note-taking, and problem-solving techniques. He stated, "I worked through problems, but most days it is direct presentation and solving of problems" because it is "a proven method" that has worked overtime. His pre-intervention rating was 11, a very low level PCK. Post-intervention, Ethan improved his teaching method; he now "incorporates some labs so the students can have some practical experience," but he still uses more direct instruction. He expounded, "I use direct instruction and any little demo… I do more labs now because of APEX, but that is not my learning style." His personal belief about teaching and his learning styles dictated his instructional method. His PCK rating increased from 11 to 33, medium level.

Teacher APD07. Before the APD training, Sue was very focused on AP scores: "I've got to have qualifying scores on the AP tests, so that guides a lot of how much time I spend on topics, or how in-depth I go into things." She stated that she has "always done hands-on activities" in the 20 years she has been teaching. She used notes and homework regularly in her instruction. Her pre-intervention PCK rating was 34, or medium level. After the training, Sue's goal on having qualifying AP scores remain unchanged. Instead, it has limited the use of reformed-based activities she believed are time consuming: "I can't spend as much time on some topics as what their *(APEX)* activities say to spend." She stated, "I have to cover the AP material before May." She also shared that her method of teaching appeals to "the goals and grade-oriented AP students in my school." Although her PCK score increased to 44, medium level, she remained within the same PCK range. The teachers' PCK rating chart is shown in Table 12. The changes in PCK level are graphically presented on Figure 7.

Table 12

Comparison of Teachers' Baseline and Intervention PCK Levels

Teachers	PCK Levels				Gains/Increase
	Baseline		Post-Intervention		
APD01	26	Medium	57	Large	52%
APD02	22	Medium	50	Large	47%
APD03	39	Medium	58	Large	32%
APD04	20	Low	46	Large	43%
APD05	24	Medium	46	Large	37%
APD06	11	Low	26	Medium	25%
APD07	34	Medium	44	Medium	5%

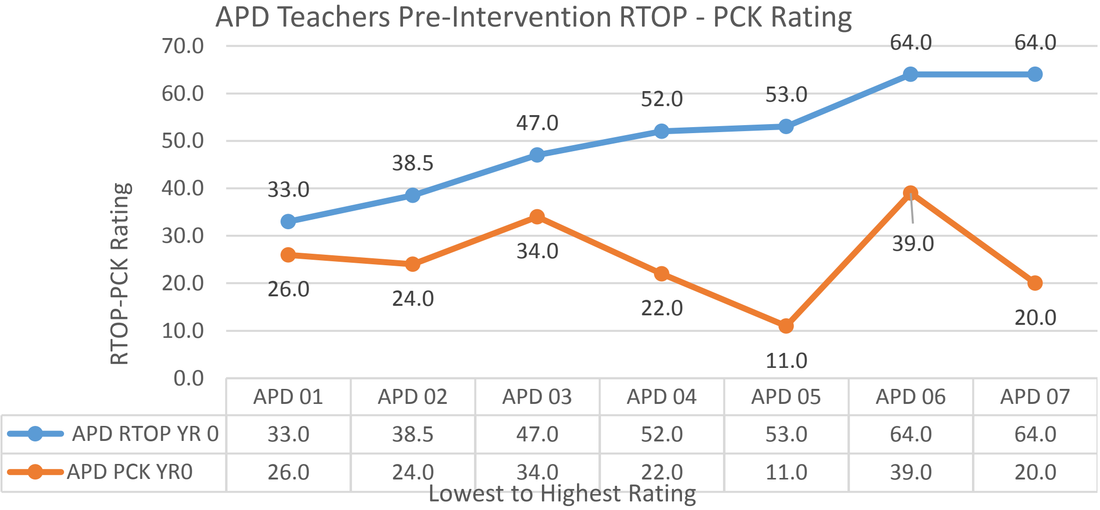


	1	2	3	4	5	6	7
Pre	11.0	20.0	22.0	24.0	26.0	34.0	39.0
Post	26.0	46.0	50.0	46.0	57.0	44.0	58.0

Figure 7. Teachers' PCK level comparison

Summary for Research Question Two (RQ2)

The researcher observed that before the APD training, the term 'hands-on activities' was used fluidly to mean 'inquiry' even where the activity was a prescribed 'cookbook' type lab or teacher-directed activity. Most labs were done after a formal introduction and the labs were used as confirmatory exercises. The lack of physics content knowledge and pedagogical skills limited the use of effective strategies. After the APD training, the teachers understood and used the term 'inquiry' more appropriately. For example, pre-intervention when teacher APD03 was asked 'what teaching method is used to accomplish her goals', she stated that she used "inquiry" after formal lecture. But post intervention she responded to the same question, "now they (*students*) are frontloaded with labs and concepts before names and then problem solving later". There was observable evidence of growth in content knowledge and pedagogical practices based on the teachers' self-report interviews and the researcher's CoRe and PaP-eRs that were generated. Overall, the teachers' PCK and self-efficacy improved as was evidenced by the changes in their instructional practice after the intervention. The teachers were more confident in using different reformed-based activities. Teacher APD02 stated, "I have moved away from standing in front of the class and telling this is what this is…now I am letting them discover on their own". Teachers APD06 and APD07 did not show as much growth in PCK as the other teachers because of their resistance to change; when asked "has your teaching changed overtime, how and why, teacher APD06 who has been teaching for 28 years stated, "when I first started teaching I was doing 'hands-on' activities anyways all the time. So that's probably how I've always taught". They continued doing what they had always done with minimal changes; this hindered their progress in implementing and utilizing the innovative ideas and practices from the APD training. All the teachers credited the APEX training for enhancing their teaching. They moved from teacher-centered instructions toward more student-focused instructional practices because of the knowledge gained. As one stated, "the APEX training got me familiar with more activities that I could give my students. So I could take more of the lecture out and put more of the activities." There was an observed relationship between teachers' use of reform practice and their PCK level. Figures 8 and 9 shows the pre and post intervention RTOP/PCK relationships.



	APD 01	APD 02	APD 03	APD 04	APD 05	APD 06	APD 07
APD RTOP YR 0	33.0	38.5	47.0	52.0	53.0	64.0	64.0
APD PCK YR0	26.0	24.0	34.0	22.0	11.0	39.0	20.0

Figure 8. Pre-intervention RTOP – PCK comparison

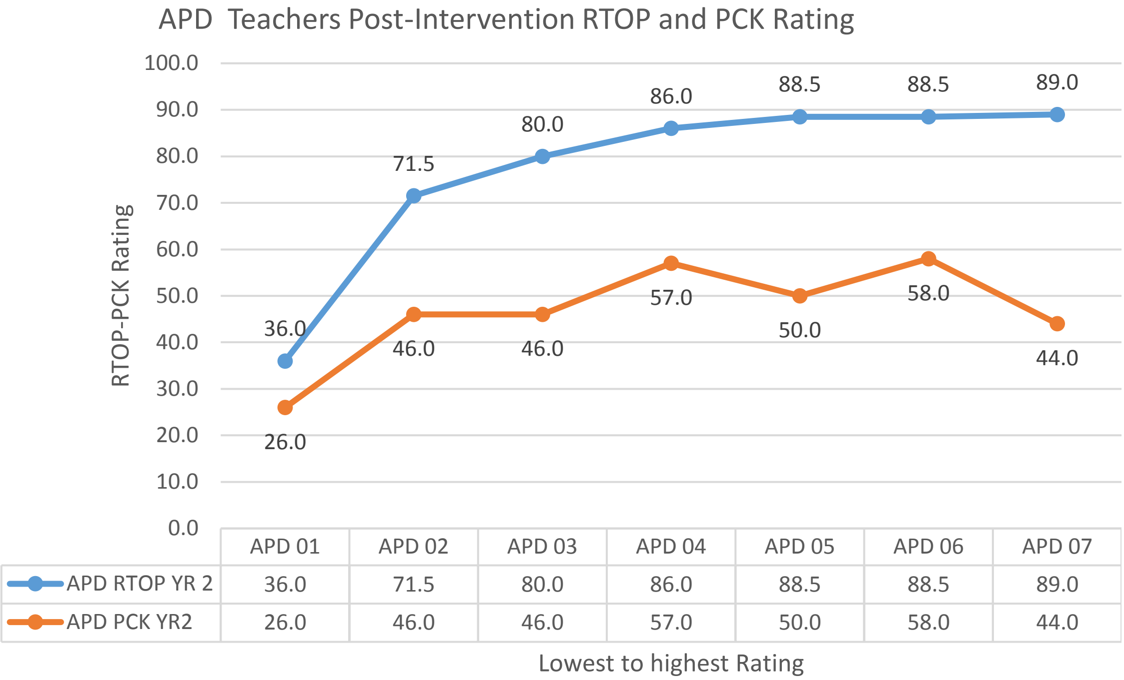


Figure 9. Post-intervention RTOP – PCK comparison

Other studies show similar relationship between PCK and reformed-oriented classroom practice; as teachers' PCK improved, the use of reform practices also increase (Desimone, 2011; Loughran, Berry, & Mulhall, 2006; NRC, 1996; Okonlawon, 2010).

Research Question Three (RQ3)

What classroom and school context factors support or impede (mediate) effective implementation of reform oriented teaching in APD and NAPD physics classrooms? This question examined how school context influenced teachers' instructional practice. Qualitative data from the interviews and questionnaires were used to respond to this question. Additional information was obtained from the schools' websites and the National Center for Education Statistics (NCES). Multiple factors were identified that supported or impeded the type of instructions used in the teachers' classrooms: teaching experience, teacher content knowledge, time, school interruptions, course scheduling/pacing, student interest, classroom resources, students' preparedness, and professional development. Four themes emerged from these factors: 1) time, 2) student characteristics, 3) resources and, 4) teacher knowledge base. These themes were classified as inhibitors and enhancers. Inhibitors were factors that the teachers identified as limiting the use of reformed-based practices while enhancers were factors that enabled the teachers to use strategies that were reformed-based. Because of the uniqueness of each school setting, the inhibitors and enhancers was examined on individual basis. The teachers' demographics and school context are shown in Table 4.

Teachers' School Settings

All of the teachers in this study taught at small to large urban and suburban schools with student population ranging from 856 to 2,850. Teachers' ages ranged from 30 to 59 years with years of teaching ranging from 2 to 28 years. Their physics teaching experience ranged between 2 to 13 years. The average teaching experience was 13 years and AP physics teaching experience was five years (See Table 5). Of the fourteen schools visited, four are Title 1 schools; more than 40% of the student population are from low-income families. The schools were eligible to use Title I funds for schoolwide programs including free and reduced lunch. All of the schools had engineering programs, offered engineering courses, or partnered with local universities that provided the courses for students. Twelve of the fourteen schools visited were predominantly white; more than 50% of the student population were Caucasian, one was predominantly black; more than 50% of the student population were African American, and one had an ethnically diverse student population. Eleven were suburban schools and three were urban schools. A case description of each teacher's school setting with the contextual factors they identified are discussed below.

The APD Group

Teacher APD01. James taught physics and a pre-engineering course at a suburban school district. He identified the AP curriculum pacing guide, school interruptions, and lack of time as factors that limited his drive to teach effectively, "the AP exams drives the instruction…and there is not enough time to plan; a situation worsened by school interruptions, especially in the spring as we are prepping for the AP exams… this is the biggest headache, time."

As a physics major, James stated, "I have the background, I feel really good, having extensive content knowledge to answer students' questions is important, you need to know more than they do." He acknowledged that attending professional development has helped in enhancing his teaching, "I went to multiple training that showed the benefit of using lab–based inquiry methods…because of that I am no longer problem-driven." In addition to training, having adequate resources has enabled him perform better as a physics teacher, "well I'm lucky I guess, I have the technology, I have the lab equipment to be able to do a lot of this."

Teacher APD02. Charles taught at a Title 1 urban school. He believed not having the physics content knowledge was a 'big hurdle' that he had to overcome through his teaching experience. He believed students' inadequate preparation and lack of interest in physics affected the instructional atmosphere: "students become less interested because of their poor math skills and physics is a heavy math-based subject, and some are in it to get an advanced diploma." Also, not having a well-resourced lab on-site limits his instruction, "the drawback is that it [resources] is picked up and I can't do things in the motion when kids ask questions on lessons covered." Charles noted that

> when he first started teaching, I was not solid enough in my math background, but now through APEX, I am learning more than what I learned in college…I feel pretty confident

> because of the amount of professional development and the few years I have under my belt teaching.

He had more confidence teaching the concepts because of the training: “I am no longer struggling to covey everything that is how the APEX program has helped me.”

Teacher APD03. In addition to teaching physics, Emily sponsored an engineering club at a suburban high school. She identified time as the biggest obstacle. “Teachers never have enough time to plan, we just don’t, my school is great, the kids are great but time is always an obstacle, you have to be committed.” The school uses open enrollment which means “anyone that wants can take the class and so some struggle due to lack of adequate preparation, especially those with misconceptions about the course.”

Emily’s formal training in engineering and her teaching experience has helped in teaching the physics course. She stated, “I took every physics class you can take in engineering but I still didn’t get a deep understanding of the physical world until I learned it with this APEX modelling method.” The knowledge gained from the training enhanced her understanding of the content. She said, “I learned it at a deeper level than I ever learned it before, I’m really buying into this method.”

Teacher APD04. In addition to teaching physics out of field, Jennifer taught an engineering elective at an urban school. She identified time as a limiting factor: “time definitely, I feel like I don’t have the time to plan it exactly the way I want to do it.” She also believed that students’ lack of interest and inadequate math skills are factors impeding her instruction. She questioned students’ real interest in physics, even though they chose to be in the class. Jennifer attributed her acquired physics content knowledge to the APD training. She stated, “the APEX training got me familiar with more activities that I could give my students. So I could take more of the lecture out and put more of the activities." Having the resources she needs has been helpful in her instruction. "I do have a pretty good supply of resources."

Teacher APD05. Michael taught at an urban school. He noted that teaching physics without the content background made him "learn a lot on my own; I read much more of the textbook, that's how I was able to piece relationships together and that helped me a lot." He still struggled with teaching the more difficult concepts such as electricity, magnetism, and optics. He noted that time was a major factor in deciding what method of instruction to use when teaching certain concepts. He stated,

> it is always a factor, given the amount of content teachers are required to cover, if I have to say what is the biggest hurdle in teaching content to students, it is time…I rarely got over half of the content, it's not feasible I have to make a choice.

Michael believed students' interest in the course enhanced how he taught. He noted, "95% of my AP kids think it is the greatest thing ever…students' enthusiasm is very contagious to a teacher and helps the teacher maintain the same level of enthusiasm." He also acknowledged that his physics knowledge has improved due to the APD training by stating "I will credit APEX for most of my recent changes in teaching." As for the classroom resources, he said that he is "in really, really good shape overall. I have a full college equip lab."

Teacher APD06. Ethan taught at a suburban school. He considered time, class scheduling, and school interruptions as factors constricting his instruction. He said, "If I have the kids for twice as long every single day, I can do a lot more one-on-one that will be ideal." Interruptions, he stated, were worse in the spring. He noted that they lose "three weeks of instruction in a school year for AP physics" so he paces himself using more lecture-based instruction to make up for the lost time. Students' interest and preparedness for class were also cited as limiting factors, noting that “some are misplaced, but most are not really equipped to take the course because of their weak math skills” hence they struggle.

Ethan recalled that before the APD training, he used cheat-sheets when working problems because he did not have the content knowledge. He proclaimed that “APEX has been wonderful for me to learn the content…I used APEX stuff for the AP exam review last year and I am very comfortable in using a variety of ways in solving problems now.”

Teacher APD07. Sue taught at an urban school that is ethnically diverse. Time is a limiting factor for her because of her focus is on students’ AP scores. She explained, “I’ve got to have qualifying scores, the AP tests guides a lot of how much time I spend on topics, or how in-depth I go into things.” She used more lectures and conducted labs about once a week; “I can’t spend as much time on some topics as what their activities *(APEX)* say to spend.” She added students’ lack of math skills as “the biggest barrier for kids in physics because they struggle with manipulating algebraic expressions and solving for a variable.” Sue stated that resources are provided for her class by science in motion. “There is no way I could do as many labs as I do if I didn’t have science in motion. I also use activities from APEX, I use white-boarding that I learned from APEX,” she explained.

The NAPD Group

Teacher NAPD08. Margaret is not a physics major but taught physics at a suburban school. Her instruction strictly followed the College Board pacing guide. She stated, “I follow the pacing guide I want to make sure I am meeting the requirements but time is a big issue.” In addition to time, she noted that some of her students “are not prepared for the physics course because of deficiencies in basic algebraic operations.” Because of her experience, Margaret had adequate content and pedagogical knowledge to make her students understand the physics concepts. But more importantly, it is her students' interest in learning physics that propels how the class is taught. She pointed out that "they self-selected the class, they chose to take AP physics, so I feel they want to be there, that makes the class dynamic instead of pulling teeth."

Teacher NAPD09. Curtis taught at a suburban school. Because he did not have a physics background, he is constantly seeking ways of improving his physics content knowledge. He believed that, to be effective, a firm understanding of physics concept is needed. His focus was on students' AP scores. He stated, "I do have to look at what is required, because they have a test at the end and I need to know the kind of materials and the kind of questions asked…what are they really looking for at the test?" Curtis said this on student interest: "most of my students are in engineering, so they are physics-minded …if kids are really engaged it makes a world of difference." His years of teaching science is an advantage to teaching physics.

Teacher NAPD10. Retha has a physics degree and taught at a suburban school but she did not have an education degree. She stated that lack of an education background sometimes hindered the use of reformed-based instruction because she does not know how. She defaulted more to lecture-based teaching because of her previous profession. She noted that time, school interruptions, and inadequate student preparation limited her instruction as well as "placing students who don't meet the requirement often makes the students struggle." Retha believed that having a firm understanding of the concepts is necessary. Also, students' interest affects how the class is taught. She said that "those in pre-engineering are very interested in physics, my students are very interested and this allowed me more freedom in what we do and how we do it." In addition, having a well-resourced lab helped. "I think I am at a good point now where I have the equipment," stated Retha.

Teacher NAPD11. Frank taught at a suburban school and is very comfortable teaching physics content because he had a physics degree. But despite having the content knowledge, he is always limited by time. He expounded, “I just feel I don’t have enough time to do what I need to do with my lesson planning, and that is the biggest problem…sometimes it is technology failure.” He believed his physics content knowledge has helped him navigate effective in his teaching: “I know physics, so I am comfortable with that.” His school is great with providing the resources and the technology needed and this has enabled him. He felt equipped by the College Board (APSI) to prepare his students to pass the AP test.

Teacher NAPD12. Jack taught at a suburban school with a unique class setting. He explained, “I have students from 9 – 12 grade, some are in calculus and others are struggling with algebra.” Although he taught physics and engineering courses out of his certified field, his biggest challenge not having enough time. “I have 60 minutes every other day, so it’s the timing of the class and what I can actually get them to accomplish in that amount of time.” His unique class set-up added to the problem of “having adequate time to accommodate the students from that broad spectrum of math abilities.” Jack’s students

> are pretty interested, very interested, my classes stay full, I usually have a lot of students that take physics 1 and they take physics 2 with me the next year… this allows me a little more freedom in what we do and how we do, we can go a little more into activities that really demonstrate concepts well.

Teacher NAPD13. Nancy had a physics degree and taught at a suburban school. School interruptions and poor class scheduling are her biggest barrier in addition to time explaining that “with the way our schedule works, every other Friday, we are not even in class so some weeks are only four days.” Students’ lack of math skills also affects how she taught the content: “I have to start from bare basics anytime we have math problems.” She believed her students’ interest was about 50/50. She stated, “half of them really like the physics because they like seeing what goes on around them, while the others are just bombed-out by the math." Nancy's physics content knowledge is an advantage. She stated, "I know physics inside, outside and upside down, it is very difficult to teach physics without that background." She had adequate resources to enhance her teaching. She said, "I actually have good resources here and we have science in motion that brings the item and set it up."

Teacher NAPD14. Rebecca taught physics at a suburban school. She had a physics degree and noted that the only issue that limited her was time. She explained that "there is a lot of things to do and finding time to fit it all in, time can be restraining and places a limit of what we do." Rebecca had a physics degree and had taught physics for many years. She stated that her students are "highly motivated and are very interested, which makes it more rewarding." Her school is "well equipped with needed resources and the technology has been a benefit." Her involvement in science in motion professional development program over ten years has been amazing and had contributed to improving her students' lab experience.

Comparing the APD and NAPD Groups

School and classroom context play a vital role in the effectiveness of teaching and learning. The diversity in a given context creates a complex social framework that can pose some challenges for the teacher and the learners. Contextual factors often interact to form the complex structure that seeks to inhibit or enhance teaching and learning. Park et al. (2005) noted that school context can moderate the efficacy of instructional practice. In examining the contextual factors influencing the use of reformed-based instruction, the following themes emerged that represented factors identified as supporting or impeding the effective implementation of reformed-based instructional practice in these settings.

Time. All of the teachers agreed that insufficient time was the biggest problem that limited effective instruction in their classroom. APD03 stated, "teachers never have enough time to plan, we just don't," and NAPD09 stated, "I just feel I don't have enough time to do what I need to do with my lesson planning and that is the biggest problem." NAPD08 stated, "Because of time to get resources together, I follow the pacing guide, I want to make sure I am meeting the requirements."

Time constraints led them to avoid instructional practices that they perceived to be time consuming. APD07 stated, "I can't spend as much time on some topics as what their (*APEX*) activities say to spend." Despite the time barrier, five of the seven APD teachers implemented more reformed-based instruction in their classrooms with the goal of enhancing their students' conceptual understanding. They were less focused on the AP "problem-based" pacing guide. APD01 stated, "I am no longer problem-driven, I want them *(students)* to take data and be able to describe what is going on." APD05 said, "My goal is for them to apply the basic principles, to have that big understanding of how all these fits together. Finally, APD04 said, "I'm not concerned really with the AP timing, I am at a good place with my instructions."

Student characteristics. Student characteristics were context-based and included student interest and preparedness in physics. Schools with predominately white students, who were in engineering programs, tended to be more interested in physics than schools with a more ethnic diverse population. NAPD09 stated that "it depends, some are really interested, most of my students are in engineering, so they are physics-minded." NAPD12 said, "my students are in taking engineering courses; they are pretty interested, very interested, my classes stay full." Finally, NAPD14 explained, "my students are highly motivated, most are in the engineering program, they are very interested in physics."

Because these students are self-motivated, the NAPD teachers tended to use more lectures, problem-solving techniques, teacher demos, and simulations so more AP materials can be covered. On the other hand, the schools where more students had poor math skills were less interested in the physics. APD02 stated, “students become less interested because of their poor math skills and physics is a heavy-math based subject.” NAPD11 said, “half of them really like the physics, the others are just bombed-out by the math.” APD07 stated that “most of the kids struggle a lot with how to manipulate algebraic equations.” Teachers in these settings struggled with effective methods to accommodate the students. NAPD11 explained, “I have to start from bare basics anytime we have math problems.” So, depending on the school context, these factors can either enhance or impede the teachers’ instructional practice.

Teacher knowledge base. Teacher knowledge base in this study mean that the teacher had the physics content knowledge, or knowledge from teaching experience, or knowledge from attending physics professional development or a combination of these factors. Having the content knowledge gave the teachers confidence in teaching the content: “I feel really good, having extensive content knowledge to answer students’ questions is important, you need to know more than they do” (APD01). NAPD11 stated, “I know physics inside, outside and upside down, it is very difficult to teach physics without that background.” NAPD09 said, “I know physics, so I am comfortable with that.” The NAPD teachers who taught out-of-field had less confidence, therefore, they used more lecture-based instructions and followed the College Board AP script. NAPD08 said, “I follow the pacing guide I want to make sure I am meeting the requirements;” this limited the use of reformed-based instructions. Five of the APD teachers reported that before APEX, they lacked the confidence because of inadequate content knowledge. They credited the APEX training for enhancing their content knowledge. Because of the new knowledge from the training, they were able to implement more reformed-based activities in their classrooms. APD02 stated, “I feel pretty confident because of the amount of professional development and the few years I have under my belt of teaching I am no longer struggling to convey everything that is how the APEX program has helped me.” APD04 followed by saying “the APEX training got me familiar with more activities that I could give my students. So I could take more of the lecture out and put more of the activities.”

Resources. All of the teachers stated that they were well-equipped for physics teaching, having the resources provided opportunity for them to use hands on activities. APD04 explained, “I do have a pretty good supply of resources,” and APD05 felt the same: “I am in really, really good shape overall. I have a full college equip lab.” Finally, NAPD14 said, “I actually have good resources here and we have science in motion that brings the item and set it up.” Having the resources needed enabled the teachers to do more with their classroom instruction.

Summary

This chapter presented data in respect to the three research questions for this study. For RQ1, the quantitative analysis showed that pre-intervention, the variances between the APD and NAPD groups, were approximately equal. Post-intervention, however, showed a statistically-significant difference in the teachers’ mean RTOP rating and a large effect size difference in the level of reformed-based instruction.

RQ2 examined the effects of physics-focused professional development on APD teachers’ PCK. The PCK Essential Components chart was used to examine if the APEX professional development enhanced the teachers’ PCK. There were observable differences between the teachers’ pre- and post-intervention PCK. Teacher ratings improved from low to medium and from medium to high level PCK. As a result of this growth, the teachers implemented more reformed-oriented instructional in their classrooms. The result showed a relationship between the teachers' RTOP rating and their PCK level, the higher the RTOP rating, the higher the PCK level. The finding is supported by existing studies that showed a relationship between teacher PCK and the use of reformed practices (Desimone, 2011; Loughran, Berry, & Mulhall, 2006; NRC, 1996; Okonlawon, 2010).

RQ3 was used to identify contextual factors that support or impede the effective implementation of reform practices in their classrooms. The study teachers reported a consensus that contextual factors often dictated the instructional choices they made. Time was the biggest factor that impeded their use of effective instructional practices, while having a good supply of resources enhanced their instructions. Student characteristics were context-based and affected the teachers' instructions differently. Above all, having the content knowledge and pedagogical skills enhanced the instruction. In all, the APD training enabled the teachers chose effective pathways to navigate through the barriers and implemented instructional methods than the NAPD teachers.

CHAPTER V:

FINDINGS, CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

Introduction

This chapter summarizes the case study results from Chapter IV. It presents a brief overview of the study and relates the findings to previous studies on the subject. It will also discuss the implications and make recommendations for future research on effective professional development and teacher quality.

Overview of Study

This study examined the influence of physics-focused professional development on the instructional practice of AP physics teachers. The overarching question was what are the effects of enhanced in-service physics focused professional development on advanced placement (AP) physics teachers' instructional practice? This question was guided by three sub-questions: 1) how does the level of reformed-oriented instruction compare in classrooms of advanced placement (AP) physics teachers who experienced in-service APEX professional development (APD) and those teachers with little or no additional in-service physics focused professional development experiences (NAPD); 2) how does participating in APEX professional development training affect advanced placement physics teachers' pedagogical content knowledge (PCK); and 3) what classroom and school context factors support or impede (mediate) effective implementation of reformed-oriented teaching in APD and NAPD physics classrooms?

This study was designed as an embedded case study to investigate a smaller group of teachers who are part of a larger population of physics teachers participating in a physics-focused professional development with the aim that further studies will be built on the findings, and generated hypotheses from this study. Quantitative and qualitative data from classroom observations, teacher interviews, surveys, and questionnaires were collected from fourteen teachers across a southeastern United States. Seven teachers who experienced additional physics-focused professional development training (intervention group) were compared to the other seven teachers who had little or no additional physics-focused professional development (comparison group). The mixed data collected were analyzed and integrated to provide information to triangulate and validate the findings.

The *Reformed Teaching Observation Protocol* (RTOP) instrument was used to collect quantitative data from classroom observations. The instrument measured the degree of reform-oriented practice in participants' classrooms (Sawada et al., 2002). Participants' mean ratings were calculated from two consecutive classroom visits based on five subscales: 1) Lesson Design and Implementation; 2) Content: Prepositional Knowledge and Procedural Knowledge; 3) Classroom culture; 4) Communicative Interactions; and 5) Student/Teacher Relationships. Classroom reform ratings could range from 0 and 100. A score of above 50 indicating evidence of some level of reformed-oriented practice (MacIssac & Falconer, 2002; Sawada et al., 2002). The RTOP data was analyzed using descriptive and inferential statistics. Due to the small sample size, effect size procedure was also used to assess and quantify the magnitude of effect the professional development had on the teachers' instructional practice. The result was used to respond to RQ1.

Qualitative data was generated from teachers' interviews, observations, surveys, questionnaires and The PCK Essential Component rubric (see Table 2). The *Content Representation* (CoRe) protocol was developed from teacher interviews and a final *Pedagogical* *and Professional-experience Repertoires* (PaP-eRs) narrative was developed based on the interview responses and the researcher's notes taken during the classroom lesson observations. The *Physics Teaching Efficacy and Belief Instrument* (PTEBI) provided survey data on how strongly participants felt about the teaching of physics. The PCK Essential Component rubric was used to capture the teachers' PCK level. Lastly, the *TIMSS AP Physics Teacher Questionnaires* provided demographic data for the teachers. The qualitative data were thematically analyzed and eight themes emerged that were used to respond to RQ 2 and RQ 3.

Summary of Findings and Conclusions

Research Question One (RQ1)

How does the level of reform-oriented instruction compare in classrooms of advanced placement physics teachers who experience in-service APEX professional development (APD) and those teachers with little or no additional in-service professional development experiences (NAPD)? The result of comparing the baseline RTOP scores for APD teachers before APEX training and the NAPD teachers without APEX training showed an overall mean classroom reformed ratings of 50.2 and 54.8, respectively. These results indicated that about one half of the sample teachers in both groups were using only basic level, or lower, of reformed-based instruction in their classrooms. A few in both groups were performing at more than a basic level reform. A rating of above 50 indicates the presence of some level of reformed teaching in the classrooms (MacIssac & Falconer, 2002; Sawada et al., 2002).

After the intervention, the sample APD teachers' mean ratings increased from 50.2 to 77.1. A comparison of the post intervention RTOP rating showed an overall mean rating of 77.1 for the APD and 54.8 for the NAPD teachers, a large effect size difference of $d = 1.15$. An overall large effect size difference of higher than $d = 0.8$ was shown in all subscales measured.

Almost all the APD physics teachers were performing at a high level of classroom reform. Only one performed at a lower level. A few in the NAPD group were performing at more than a basic level of reform. Only one performed at a high level. This increase in ratings and large effect size difference indicated there was an observable shift in the level of reformed-based practices occurring in the APD classroom as a result of the training. The APD teachers were using more effective teaching strategies that were student-centered compared to the teacher-centered and problems solving strategies used by the NAPD teachers.

This finding is consistent with other research. Barlow et al. (2014) reported that all but two of the nine participants in their study demonstrated increase in their total RTOP scores which resulted in the increased level of reformed instruction used by the participants. Lakshmana et al. (2011) also reported that there was significant growth in the extent to which teachers' implemented inquiry-based instruction in the classroom after participating in a standard-based professional development. Borko (2009) reported that professional development training helps teachers "enhance their knowledge and develop new instructional practices" (p. 3).

The data indicated that only one of the seven APD teachers reported to have physics majors and one engineering major in their bachelor's degree unlike the NAPD group who had greater physics discipline content knowledge CK with five teachers reported to be physics majors in their bachelor's degree. However, the NAPD teachers did not transfer their physics knowledge into practice (PCK). They appeared to lack pedagogical content knowledge; hence, they used more teacher-centered instructional practice. To be able to transform discipline content knowledge, the teacher had to have a repertoire of teaching strategies focused on students learning, and the ability to use pedagogical content knowledge in a resourceful, creative, and flexible manner in planning and teaching (Baumert et al., 2010; Findell, 2007).

The data also showed that before the APEX training five APD teachers who did not have adequate CK and the pedagogical skills to teach physics. But post-intervention, they gained conceptual understanding of the physics content and the knowledge of teaching strategies based on the activities and resources provided by the program. Ojose's (2012) report noted that "we cannot teach what we do not know; content knowledge is needed and we cannot effectively teach content we know quite well, if we lack knowledge of teaching" (p. 151). Teachers who do not have adequate CK and the pedagogical skills to effectively teach the physics content often used traditional, teacher-centered, and textbook-based methods. Desimone (2011) noted that a teacher with limited knowledge will tend to use rote memorization and procedural teaching method and will often miss great teaching opportunities of connecting concepts and representations for the learner.

Research Question Two (RQ2)

How does participating in APEX professional development training affect advanced placement physics teachers' pedagogical content knowledge (PCK)? Based on the data analyses, four themes emerged that were used to respond to RQ2: 1) teacher knowledge; 2) teaching practice; 3) teacher belief; and 4) teacher persuasion. These themes were used to identify and explain the effect of the APD intervention on the teachers' PCK. The researcher developed a PCK Essentials Rubric to examine if the intervention improved the APD participants' discipline content knowledge (DCK); pedagogical knowledge (PK); and pedagogical content knowledge (PCK). The PCK Essentials Component Rubric instrument determined whether these three knowledge domains were used in isolation or integrated in teaching the subject. The APD group's baseline data indicated that the teachers' PCK were in the 'low to medium' level. After the APD intervention, their PCK level increased from 'low to medium' for one teacher and 'medium to high' for all the other teachers. The APEX model training enhanced the PCK level of the teachers. The Lakshmana et al. (2011) study supported the finding that there was significant growth in the extent to which teachers' implemented inquiry-based instruction in the classroom after participating in professional development. Other studies reported positive changes in participants' PCK after they participated in professional development.

The data analyses also showed that the APD teachers' enhanced PCK impacted their self-efficacy. The teachers' self-rating on the pre- and post-intervention PTEBI survey indicated changes in the self-efficacy (PPTE) component but very little change in the beliefs outcome (PTOE). The baseline ratings were found to be higher than their post-intervention rating. A negative correlation was found. As the PCK level increased, the self-efficacy decreased. This finding was at variance with studies that report significant growth in teacher self-efficacy after professional development or that there was a positive correlation between changes in the use of inquiry-based instructions and changes in teacher self-efficacy (Lakshmana et al., 2011; Lumpe et al., 2012).

A plausible explanation for this result is that as the teachers' gained new knowledge, it challenged the existing beliefs and they discovered how much they did not know; hence, they scored themselves lower on the self-reporting PTEBI. The reasoning was supported by Powell-Moman and Brown-Schild (2011) who noted that teachers judged their self-efficacy based on their current pedagogical content knowledge, but after the received professional development, they judged their later classroom performance and confidence based on their now increased content knowledge and pedagogical knowledge. Desimone (2011) agreed that effective professional development changes teacher knowledge and alters their beliefs.

Lastly, this study found a positive relationship between participants' PCK and the level of reformed-oriented instruction. As teachers' PCK improved, their observed instructional practice also improved and they implemented more reform-based practices in their classrooms. This finding is supported by Park et al.'s (2010) study reporting that a teacher's PCK level was positively related to the extent to which the teacher's instruction was reformed. This finding aligns with other studies that indicated that teachers who improve their PCK used effective instructional practice that leads to higher student achievement (Borko, 2009; Clewell et al., 2004; Darling-Hammond, 1999; Desimone, 2011; Mundry & Boethel, 2005; Ingvarson, Meiers, & Beavis, 2005). Teachers who are effective in the classroom often "employ components of PCK in an integrated fashion as they plan and carry out instruction" (Abell, 2008, p. 1407).

As the participants combined all components of knowledge gained, they increased their PCK and teaching repertoire. A teacher's repertoire of teaching strategies is largely dependent on the breadth and depth of their conceptual understanding of the subject, and the pedagogical knowledge enables them to be resourceful, creative, and flexible in planning and teaching (Baumert et al., 2010; Findell, 2007). Increasing the repertoire for the physics teacher affects how particular physics topics/concepts, problems, and issues are organized, presented, and modified for the different levels of learners in the classroom (Crouch, Watkins, Fagen, & Mazur, 2007; Fisher, 2004). Lederman and Gess-Newsome (2011) noted that teachers with physics PCK are more likely to facilitate meaningful learning outcomes in secondary school students.

Research Question Three (RQ3)

What classroom and school context factors support or impede (mediate) effective implementation of reformed-oriented teaching in APD and NAPD physics classrooms? The data analyses for RQ3 indicated that school context played a role in how reformed-based instruction was implemented in the schools observed. Four themes that emerged that were used to respond to this question: 1) time, 2) student characteristics, 3) school resources, and 4) teacher knowledge base. These factors were shown to influence the instructional practice used by the teachers. Bloom et al. (2010) believe that contextual factors that impede effective practices may include personal challenges: lacking the experience/content knowledge, pedagogical issues, contextual factors within the school, administrative support, etc. Park et al. (2005) noted that school context can moderate the efficacy of instructional practice. For this study, time and teacher knowledge base were found to impede the implementation of reformed based instructions. These two factors were not context-based because all the teachers stated during the interviews that the factors limited their instructional practice. Teacher time, which included planning time and instructional time, was the biggest factor that hindered the participants, especially with the AP curriculum. NAPD14 stated, "there is a lot of things to do and finding time to fit it all in, time can be restraining and places a limit of what we do." The teachers stated that the lack of teacher time was worsened by school interruptions and poor class scheduling. This result aligns with Paek et al. (2005) who reported that because of time constraints, 84-92% of teachers in their study favored instructional strategies that involved a shorter time frame to a cover larger amount of content over highly involved and 'time consuming' strategies. As a result, teachers in this study used 'mostly lecture' as the predominant method of teaching and ignored research-based methods.

Most NAPD teachers did not demonstrate an adequate level of PCK, which limited the implementation of reformed-based practices. For example, teachers NAPD10 and NAPD14's lack of an education degree may have affected the instructional practice. This was evident in their observed RTOP rating of 36 and 32, respectively. Of the fourteen teachers in this study, six who had physics content knowledge lacked the pedagogical skills to transform the knowledge in a meaningful way. A comparison of the pre-APD and NAPD teachers' RTOP ratings showed that the teachers with physics background were rated in the low-below 50-and moderate-below 65 range. (MacIssac & Falconer, 2002; Sawada et al., 2002).

The other seven teachers who did not have physics degrees/background struggled more because they lacked the CK and PCK to use strategies and activities that engage and improve students' learning. These teachers may have added more to their knowledge based than the others because teachers with physics major may be more resistance to change. The PCK rating of the NAPD teachers is shown in Appendix G. Sunal, Sunal, and Wright (2006) noted that teachers are not able to fully implement reformed-oriented instruction in their classrooms because they do not know how. For the NAPD teachers PCK chart (see Appendix G). Multiple studies outline the importance of PCK in effective instructional practice. They noted that the lack of PCK hinders teachers from using the most appropriate instructional strategies needed to facilitate meaningful learning (Borko, 2009; Desimone, 2011; Mundry & Boethel, 2005; Ingvarson, Meiers, & Beavis, 2005; Paek et al., 2010). PCK enables the teacher to self-regulate, be resourceful, and creatively develop alternative plans based on the flexibility of having the knowledge (Findell, 2007).

Student characteristics were presented as student preparation and student interest. This factor was context-specific because it played different roles in different school settings. For instance, teachers in schools with more white students participating in engineering and math-based program stated that their students were interested in physics. Rebecca, NAPD14, stated, "it is more rewarding for the teacher if you have students that are interested." She teaches in a predominately white school with most of her students in engineering programs. But schools where the students were not as involved in engineering or math-based programs were not as prepared or equipped; they showed less interest in physics. This slowed down the pace of the class because more time is used in remediation; NAPD13 stated, “I have to start from bare basics anytime we have math problems.” Faced with less time to cover the material, these teachers result to instructional practices/activities that are deemed ‘less time consuming.’ Therefore, student interest and preparation negatively influenced the type of instruction used in these types of school context.

The teachers’ physics instructional resources was the only factor identified by all the teachers as enhancing the implementation of reformed practice in the classroom. The teachers stated that they had well-resourced laboratory and classrooms; NAPD11 said, “the equipment is one that contributes to the effectiveness of my teaching,” and APD05 said, “I am in really, really good shape overall. I have a full college equip lab.” Where the resources were not on-site, they were provided by the state supported Alabama Science in Motion Program; APD07 stated, “there no way I could do as many labs as I do if I didn’t have science in motion.”

Overall, these factors were more teacher-dependent and less context-based-dependent because post-intervention, the APD teachers were able to implement more reformed-based practices that engaged their students. The APD teachers shifted from teacher-centeredness to a more student-led environment. They were more prepared and equipped to navigate through these mitigating factors because of increased levels of PCK. Woolfolk Hoy et al. (2009) confirmed that enhanced PCK allows the teacher to adjust more readily to the context by making sense of the dynamics of the class but inadequate PCK often led to lack of confidence in teaching to the use of more lecture-based instruction and the de-emphasis or avoidance of inquiry methods. This finding supports Desimone’s (2009) report that student characteristics, teacher characteristics, and school characteristics can influence the effective implementation of gains from professional development training. In addition, Main and Virtue (2015) reported that where professional development training is aligned with school context, the teachers more readily adapted and implemented the improved physics teaching in their classrooms.

Limitations

This study was limited by the following:

1) The goal of the classroom observation was to evaluate the level of reformed-based instruction used by the teacher. Teacher classroom were visited for two consecutive days and the observation focused on the particular lessons presented for those periods. Observing the lesson only twice may not have provided enough information on the teacher classroom practice as would an observation of an entire unit.
2) The second limitation was related to sample size and selection criteria. The selection of participants was limited by the number of AP physics teachers in the cohort used from the APEX program and the type of AP course they taught. A larger sample population may have provided a more robust data and opportunity to pair-match the teachers from the two groups for better comparison.
3) The third limitation was the threat to internal validity of the study. This included the study design, the effect of time; years of teaching, teacher level influence, and maturation of the comparison group. Other threats include the effect of intervention from other sources and other alternative explanations that were not considered in this study. With effects of these confounding factors, the finding of the study cannot assert causality.
4) Although the study mirrors a larger study, the small sample size used for the study does not allow for generalizability of the findings, however, the current findings does provide

for hypothesis generation that provides for new insights that warrants further investigation.

Implications of Study

Discipline-focused Professional Development

A reformed-oriented classroom depends largely on teacher quality. This study demonstrated the need for further investigation of the need for additional enhanced physics-focused professional development for AP physics teachers beyond traditional AP training. It was evident from the data collected in the sample that it is questionable that physics teachers do not have adequate content background and pedagogical content skills for physics instruction. The needs in the physics classrooms may be met through discipline-focused professional development that targets specific groups of teachers, providing the knowledge base, CK and PCK, to effectively teach the content and ensure students' learning demands are met (Desimone, Smith, & Ueno, 2006).

Framing Professional Development Training

Professional development should not only be tailored to specific content areas but it must have specific goals and objectives that will have an impact on the participants. Because the APEX program embraced the five components of effective professional development for the sample, the teachers were able to gain, retain, and transfer the knowledge to their classrooms. Teachers who participate in professional development activities with core features that emphasize content knowledge, active learning, concept coherence, collective participation and is continuous are more likely to experience needed changes and enhanced PCK (Desimone, 2011). The research literature reported positive effects on teacher instructional practice and student learning when the five core features are used in framing a professional development (Blank &

Alas, 2008; Jeanpierre et al., 2005; Yoon et al. 2007) and that teachers who receive over 100 hours of professional development demonstrate consistent positive effects on their instruction (Banilower et al., 2006; Lumpe et al., 2012; Paek & Ponte et al., 2005). The APD teachers received about 256 hours of additional in-service training after two years of their three-year training.

Recommendations for Future Research

This embedded case study presented initial empirical evidence on the influence of enhanced physics focused professional development on the instructional practice of a small population of advanced placement physics teachers in a southeastern United States. Based on the sample size and the findings, the following hypotheses for further research have been generated.

First, despite sample size, the result showed a large effect size difference with respect to the outcome treatment on the intervention group compared to the comparison group. This provides evidence and justifies a more rigorous and robust inquiry that investigates further the causal effect of the intervention on participants using a larger population of advanced placement physics teachers.

Second, the goal of the APD intervention was to teach the physics teachers to reach their students. This study found an observable difference between the APD teachers PCK level during pre- and post-intervention. This finding can be strengthened by further study that connects or establishes causality of the intervention on teachers' PCK leading to students' AP examination or other learning outcomes. On the other hand, an extension of the study could explore how participating in an enhanced physics-focused professional development and changes in teacher instructional practice influence students' perception and interest in learning physics.

A third area of research should focus on instrument development that provides an effective assessment tool to capture adequately the content knowledge needed to be an effective content teacher. The researcher in this study developed a PCK Essential Component rubric that was used to identify the teachers' PCK level based on research literature and findings from this study. The instrument needs to be empirically validated in a larger sample study.

Fourth, due to the current changes in the AP Physics 1 curriculum and the move toward more conceptual teaching and learning of the physics concepts, a comparative study may be needed to examine the effect of College Board training on AP teachers and how emphasis on the mathematical aspect of problem-solving differs from more emphasis on conceptual understanding.

Fifth, with the larger population of teaches in the APEX program, a study that compares the AP and non-AP physics teachers is necessary to determine if the results will be similar or different groups with different characteristics.

Lastly, the APEX training provided the teachers a platform to collaborate as part of a professional learning community; it would be useful to examine beyond the AP training how the teachers in 'isolated classrooms' strive to collaborate with each other in a professional learning community outside their schools and what this collaboration, or lack of, is doing to sustain the effectiveness and growth of their PCK.

Conclusion

This study explored the effect of an intervention on the instructional practice of advanced placement physics teachers. Many of the high school physics classrooms in a southeastern state where this study was conducted are filled with teachers who are tasked with teaching the course that they are not adequately prepared or certified to teach and in which they do not have continued in-service follow-up preparation. Most of these teachers struggled because they lack either the specific subject CK, or PCK, or both to facilitate and implement highly effective learning for their students. The lack of discipline specific knowledge and instructional skills, often led to the use of direct instruction, problem-solving, and activities that are teacher-led. This initial finding indicates provide insights to inform future studies and generated additional hypotheses:

1. When physics teachers lack the pedagogical knowledge on how to transform the physics content into meaningful learning for the students they struggle with the low self-confidence.
2. Traditional teacher-centered instruction is less productive in making students learn physics conceptually.
3. Lack of adequate and continued professional development of advanced placement physics teachers hinders effective use of reformed-oriented instruction.
4. There is a need for a content-focused professional development that targets AP physics teachers to ensure students' learning needs are met.
5. The observed growth in the APD teachers' content knowledge and PCK can be attributed to the continuous enhanced training they received over the two-year period.
6. Contextual factors that limit the implementation of reformed-based practice are more teacher-dependent than context-based, because teachers who do not have adequate PCK struggle to navigate through school and classroom context issues.

Professional development should be a platform to train and develop teachers to use reformed-oriented teaching that makes student-centered learning possible (Capps et al., 2012).

The enhanced PCK enriched how the APD teachers planned and implemented reformed-oriented instruction in their classrooms. They also experienced a paradigm shift in their self-efficacy based on the new sets of knowledge acquired. This result is consistent and compares to reports from larger studies with the APEX group as a whole (Sunal et al., 2015, 2017).

The APD teachers participated in over 250 hours of physics-focused professional development unlike most of the NAPD teachers who had less than 35 hours of training beyond their AP training; APD teachers were found to be more willing to experiment with new teaching methods to better serve the needs of the students. APD04 stated, “the APEX training got me familiar with more activities that I could give my students. So I could take more of the lecture out and put in more of the activities.”

Students’ lack of interest and engagement in physics cannot be addressed without first investigating the need for adequate teacher preparation and how specific science content is represented to have a meaningful effect on the learner (Banilower, 2013; Park et al., 2010; Rozenszajn & Yarden, 2014).

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APPENDIX A:

AN OVERVIEW OF KEY LITERATURE APPLICABLE TO THIS STUDY

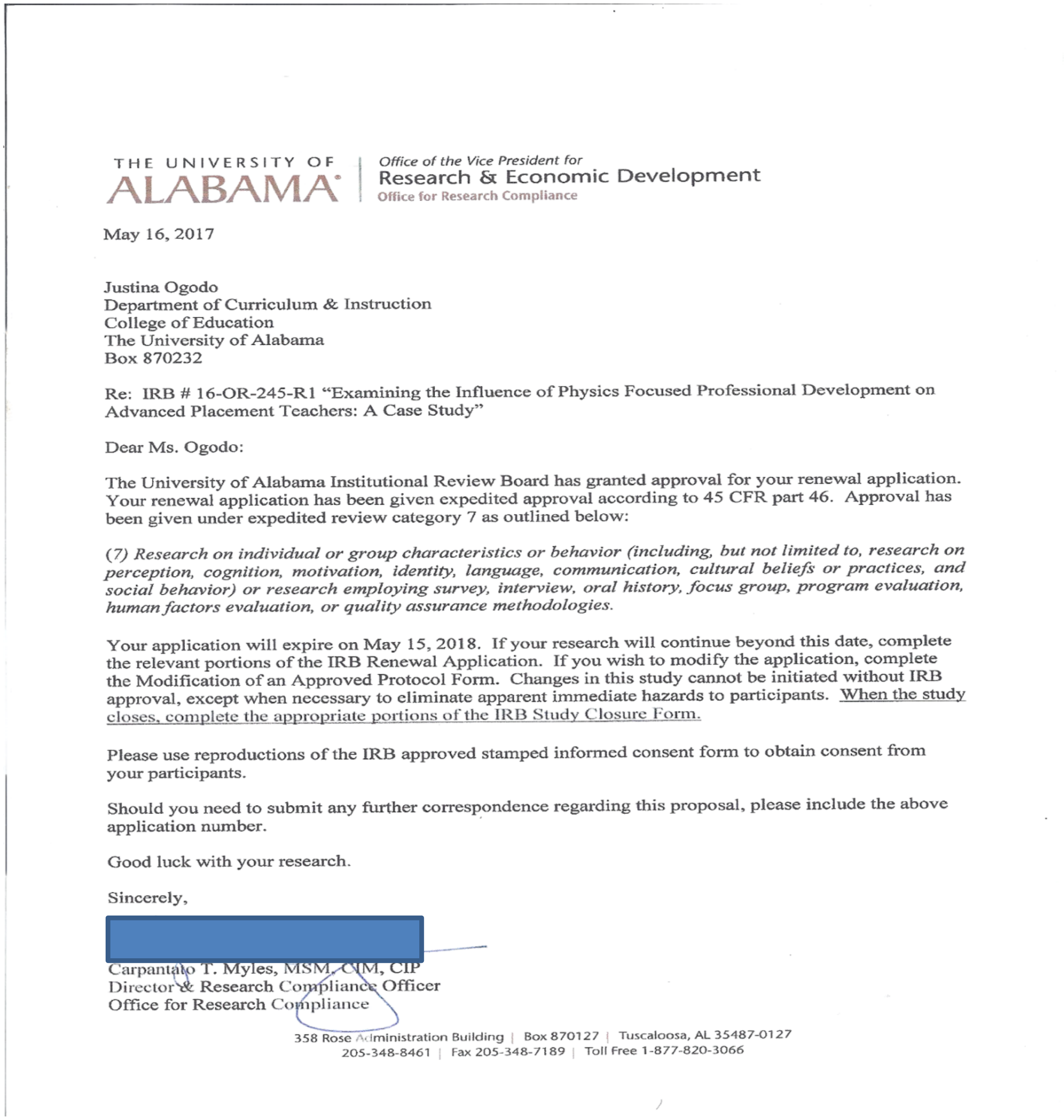
Sources	Purpose	Sample	Method/ Instrument	Findings
Abd-El-Khalick, F., Boujaoude, S., Duschl, R., Lederman, N. G., Mamlok-Naaman, R., Hofstein, A., & Tuan, H. L. (2004). Inquiry in science education: International perspectives. *Science education*, *88*(3), 397-419.	To determine how inquiry is perceived and enacted in the classroom of six countries and to examine factors that facilitate or impede inquiry-based science education.	Six symposium participants.	Qualitative Method / Comparative analysis.	The researchers found that conceptions of inquiry and classroom enactment are highly contextualized and that most science teachers have never directly experienced authentic scientific inquiry during their science education or within their teacher education programs, therefore, they were unable to enact or use inquiry in their classroom.
Banilower, E. R., Smith, P. S., Weiss, I. R., Malzahn, K. A., Campbell, K. M., & Weis, A. M. (2013). *Report of the 2012 national survey of science and mathematics education.* Chapel Hill, NC: Horizon Research, Inc.	To describe the status of physics education in America.	472 teachers.	Quantitative survey.	The result indicated that only 23% of the 472 participants in the survey had degrees in physics. They also found that compared to other science teachers physics teachers were more likely to teach multiple subjects.
Buczynski, S., & Hansen, C. B. (2010). Impact of professional development on teacher practice: Uncovering connections. *Teaching and Teacher Education*, *26*(3), 599-607.	To measure the impact of PD intervention on teacher practices and students' science achievement and to determine if teachers implemented inquiry-based instruction from the PD in the classroom.	118 science teachers and 3,450 students from two urban school districts.	Qualitative case study /focus group, pre- and post-subject matter exams, teacher surveys, classroom observations, and student achievement scores.	The researchers found that contextual barriers such as inadequate time allotted for science instruction by schools and districts, the mandate to teach certain curriculum, lack of teaching resources, classroom management issues, etc. limited the implementation of knowledge gained from a professional development training.
Lakshmanan, A., Heath, B. P., Perlmutter, A., & Elder, M. (2011). The impact of science content and professional learning communities on science	This study examined the impact of standards-based PD on teacher efficacy and instructional	Between 65 -107 teachers over a 3-year period	Mixed method, pre-posttests, survey, interview observation and focus	They found growth in teacher efficacy and use of inquiry-based instruction but not in outcome expectancy. They also observed a positive correlation between changes in self-efficacy and changes in the use of inquiry-based

teaching efficacy and standards-based instruction. *Journal of Research in Science Teaching*, *48*(5), 534–551.	practice of elementary and middle school science teachers.		group.	instruction and the two components mutually influence each other.
Park, S., Jang, J. Y., Chen, Y. C., & Jung, J. (2010). Is Pedagogical Content Knowledge (PCK) necessary for Reformed Science Teaching? Evidence from an Empirical Study. *Research in Science Education*, *41*(2), 245-260.	To investigate the correlation between teachers' PCK level and the degree of classroom reform-oriented instruction.	Seven high school biology teachers.	Quantitative research.	The investigators found that the "level of a teacher's PCK is highly connected with the degree to which his or her instruction is reform-oriented" (p. 252).
Penuel, W., Fishman, b. J., Yamaguchi, R. Gallagher, L. (2007). What Makes Professional Development Effective? Strategies. That Foster Curriculum implementation. *American Educational Research Journal*. *44*(4), pp. 921 –958	To examine the effects of different characteristics of professional development on teachers' knowledge and their ability to implement the program.	454 science teachers.	Survey/ Archival data, interview.	Data analysis showed that additional PD had significant impact on teacher knowledge and preparedness toward inquiry in the classrooms and that there was a positive impact on the participants after experiencing a meaningful, ongoing-coherent PD that was consistent with their school and district, which encouraged implementation in their classroom.
Rozenszajn, R. & Yarden, A. (2014). Expansion of Biology Teachers' Pedagogical Content Knowledge (PCK) During a Long-Term professional development Program. *Research Science Education. 44*, 189–213	To examine if participating in a long-term (2-year) professional development expanded teachers' pedagogical content knowledge.	3 teachers.	Grounded theory, Qualitative, teacher interview, workshop materials.	The result indicates that the program provided a meaningful platform for teachers to expand their PCK and that while each teacher was influenced by different activities at different levels, all three teachers' experienced meaningful expansion of their PCK during the final stage of the program.
Saunders, R. (2014). Effectiveness of Research-Based Teacher Professional development. *Australian Journal of Teacher Education*, *39*(4), 166-184.	The effectiveness of research-based teacher professional development.	27 teachers	Mixed method, survey, questionnaire, interview, and classroom observation	The researcher found that "teachers mold their practices to suit the needs of their immediate environments because what may work for one teacher in one context may hinder another in a different situation" (p. 167).
Sunal, D. W., & Wright, E. L. (2014). Research in Science Education: Volume 2. The Impact of State and National Standards in	To understand the impact of science standards on teacher classroom practice.	141 elementary, middle, high school teachers.	Teacher survey/ Quantitative	The study indicates that many teachers were either not familiar or were confused about the goals and purpose of the state standards, therefore, they could not fully implement the standards in their

K–12 Science Teaching. Greenwich, CT: Information Age Publishing; 2006.				classrooms. Teacher inability to effectively implement the standards was attributed to “lack of adequate professional development for a majority of teachers” (p. 147).
White, S. & Tesfaye, C. I. (2014). High school physics courses and enrollments-Results from the 2008-09 nationwide survey of high school physics teachers. Focus On. American Institute of Physics Statistical Research Center. 1-8.	The status of high school physics courses and enrollment	3,553 schools.	Quantitative survey.	The researchers found that although there was a 19% increase in students’ enrollment between 1987 and 2013, the increase was not matched by an increase in the number of qualified teachers, therefore, more students are taking physics from teachers who are inadequately prepared than ever before.

APPENDIX B:

INSTITUTIONAL REVIEW BOARD APPROVAL LETTER



THE UNIVERSITY OF
ALABAMA
Office of the Vice President for
Research & Economic Development
Office for Research Compliance

May 16, 2017

Justina Ogodo
Department of Curriculum & Instruction
College of Education
The University of Alabama
Box 870232

Re: IRB # 16-OR-245-R1 "Examining the Influence of Physics Focused Professional Development on Advanced Placement Teachers: A Case Study"

Dear Ms. Ogodo:

The University of Alabama Institutional Review Board has granted approval for your renewal application. Your renewal application has been given expedited approval according to 45 CFR part 46. Approval has been given under expedited review category 7 as outlined below:

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Your application will expire on May 15, 2018. If your research will continue beyond this date, complete the relevant portions of the IRB Renewal Application. If you wish to modify the application, complete the Modification of an Approved Protocol Form. Changes in this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants. When the study closes, complete the appropriate portions of the IRB Study Closure Form.

Please use reproductions of the IRB approved stamped informed consent form to obtain consent from your participants.

Should you need to submit any further correspondence regarding this proposal, please include the above application number.

Good luck with your research.

Sincerely,

[redacted]

Carpantato T. Myles, MSM, CIM, CIP
Director & Research Compliance Officer
Office for Research Compliance

358 Rose Administration Building | Box 870127 | Tuscaloosa, AL 35487-0127
205-348-8461 | Fax 205-348-7189 | Toll Free 1-877-820-3066

APPENDIX C:

PARTICIPANT CONSENT FORM

AAHRPP DOCUMENT #192
UNIVERSITY OF ALABAMA
HUMAN RESEARCH PROTECTION PROGRAM

Study title: Examining the Influence of Physics Focused Professional Development on Advanced Placement Teachers - A Case Study

Investigator's Name: Justina Ogodo

Position: Doctoral student

Institution: The University of Alabama

You are being asked to take part in a research study. This study is called **"**Examining the Influence of Physics Focused Professional development on Advanced Placement Teachers". The study is being done by Justina Ogodo, a graduate student at the University of Alabama. Mrs. Justina Ogodo is being supervised by Professor David Sunal, a professor in the college of Education at the University of Alabama.

Is the researcher being paid for this study? No. The researcher is not receiving payment for this research.

Is this research developing a product that will be sold, and if so, will the investigator profit from it? No.

Does the investigator have any conflict of interest in this study? No.

What is this study about? What is the investigator trying to learn?
This study will examine the influence of physics focused professional development on advanced placement physics teachers in the state. The investigator hopes to learn if participating in additional physics focused in-service professional development improve participants' instructional practice.

Why is this study important or useful?
Your views and comments will provide information that may strengthen the use of physics focused professional development in improving the teaching of physics in the state.

Why have I been asked to be in this study?
You have been asked to be in this study because you are an advanced placement physics teacher in a secondary institution in the state and because of your involvement in a physics focused professional development program.

How many people will be in this study?
About twelve people will be in this study.

What will I be asked to do in this study?
If you meet the criteria and agree to be in this study, you will be asked to do these things: Complete a survey and a questionnaire concerning your classroom experience. You will be observed teaching physics in your classroom. You will also be interviewed. The interview will be audio-recorded and transcribed verbatim. You may choose not to be audio-recorded.

☐ Yes ☐ No I agree for the interview to be audio-recorded.

How much time will I spend being this study?
The survey and questionnaire will take about 30 minutes each to complete. Interview should last about 25 – 30 minutes depending on how much information you choose to share. Your classroom will be observed for about 50 minutes for two consecutive days. The entire study will take about 3 hours of your time over two days.

Will being in this study cost me anything?
The only cost to you from this study is your time.

Will I be compensated for being in this study?
In appreciation of your time, you will receive a gift card in the amount $75 dollars after the completion of the entire data collection process.

Can the investigator take me out of this study? *Yes.*

What are the risks (dangers or harms) to me if I am in this study?
There is no potential risk associated with this study.

What are the benefits (good things) that may happen if I am in this study?
Your feedback may provide useful information to understand effective ways of improving the teaching and learning of physics in high schools. We cannot or do not guaranty or promise that you will receive any benefit from this study.

What are the benefits to science or society?
This study will help schools by providing information on professional development that will enhance the teaching and learning of physics and the society in general.

How will my privacy be protected?
Interviews will be protected by conducting it in a quiet space at your school. Survey and questionnaire can be filled privately at your school or at your home. You will not have to answer

any question that you do not want to answer. Pseudonyms will be given to all participants in the study.

How will my confidentiality be protected?
To maintain confidentiality, no personally identifiable information will be obtained or used. All information gathered from the interview, survey, and questionnaire will be stored in a locked cabinet for six years after the completion of the study. Due to the small sample size and the number of advanced placement teachers in the state, there is that possibility that you may be identified when the findings are publicized. It is important that you understand the risk before you agree to participate in the study. All information gathered will be destroyed after the six year period.

☐ Yes ☐ No I acknowledge that I may be identifiable during this study.

What are the alternatives to being in this study? Do I have other choices?
The alternative to being in this study is not to participate.

What are my rights as a participant in this study?
Taking part in this study is voluntary. It is your free choice. You can refuse to be in it at all. If you start the study, you can stop at any time, however, if you do not complete the entire data collection process, **you will not receive the $75 gift card**. There will be no effect on your relations with the University of Alabama.

The University of Alabama Institutional Review Board ("the IRB") is the committee that protects the rights of people in research studies. The IRB may review study records from time to time to be sure that people in research studies are being treated fairly and that the study is being carried out as planned.
In some studies the federal government or the study sponsor (NIH, NSF) may review study documents. If new information becomes available that might affect your willingness to continue participating in this study, we will tell you.

Who do I call if I have questions or problems?
If you have questions, concerns, or complaints about the study right now, please ask them. If you have questions, concerns, or complaints about the study later on, please call the investigator Justina Ogodo at (205) 422-0380. If you have questions about your rights as a person in a research study, call Ms. Tanta Myles, the Research Compliance Officer of the University, at 205-348-8461 or toll-free at 1-877-820-3066.

You may also ask questions, make suggestions, or file complaints and concerns through the IRB Outreach website at http://osp.ua.edu/site/PRCO_Welcome.html or email the Research Compliance office at participantoutreach@bama.ua.edu.

After you participate, you are encouraged to complete the survey for research participants that is online at the outreach website or you may ask the investigator for a copy of it and mail it to the University Office for Research Compliance, Box 870127, 358 Rose Administration Building, Tuscaloosa, AL 35487-0127.

I have read this consent form. I have had a chance to ask questions. I agree to take part in it. I will receive a copy of this consent form to keep.

Signature of Research Participant	Date
Signature of Investigator	Date

APPENDIX D:

REFORMED TEACHING OBSERVATION PROTOCOL

I. BACKGROUND INFORMATION

Instructor/teacher Code # _______ Announced Observation?_____________
(yes or no, or explain)

Location of class ____
(university, building, room/school district, school, room)

Lesson Observed _________________ Year/Grade Level ____________________________

Observer ______________________________ Date of Observation _____________

Start time ______________________________ End time _______________________

II. CONTEXTUAL BACKGROUND ACTIVITIES

In the space provided below please give a **brief description of the lesson observed**, the **classroom setting** (space, seating arrangements, etc), **and learning climate** in which the lesson took place (cooperative groups, teacher & student attitudes toward learning, classroom management strategies used etc), and **any relevant details about the students** (number, gender, ethnicity), **teacher, building climate, administrative constraints, and other factors not covered in RTOP** that you think are important for RTOP and other qualitative analysis that will lead to completion of the final report for the site visit. Use diagrams and more pages if they seem appropriate and are needed.

Record salient events observed here that you will use in completing RTOP.

Time	

III. LESSON DESIGN AND IMPLEMENTATION

		Never Occurred				Very Descriptive
1)	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	**0**	**1**	**2**	**3**	**4**
2)	The lesson was designed to engage students as members of a learning community.	0	1	2	3	4
3)	In this lesson, student exploration preceded formal presentation.	0	1	2	3	4
4)	This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	0	1	2	3	4
5)	The focus and direction of the lesson was often determined by ideas originating with students.	0	1	2	3	4

IV. CONTENT

Propositional Knowledge

6)	The lesson involved fundamental concepts of the subject.	0	1	2	3	4
7)	The lesson promoted strongly coherent conceptual understanding.	0	1	2	3	4
8)	The teacher had a solid grasp of the subject matter content inherent in the lesson.	0	1	2	3	4
9)	Elements of abstraction (i.e., symbolic representation, theory building) were encouraged when it was important to do so.	0	1	2	3	4
10)	Connections with other content disciplines and/or real world phenomena were explored and valued.	0	1	2	3	4

Procedural Knowledge

11)	Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	0	1	2	3	4
12)	Students made predictions, estimations and/or hypotheses and devised means for testing them.	0	1	2	3	4
13)	Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	0	1	2	3	4
14)	Students were reflective about their learning.	0	1	2	3	4
15)	Intellectual rigor, constructive criticism, and the challenging of ideas were	0	1	2	3	4

valued.

V. CLASSROOM CULTURE

Never Occurred — Very Descriptive

Communicative Interactions

16)	Students were involved in the communication of their ideas to others using a variety of means and media.	0	1	2	3	4
17)	The teacher's questions triggered divergent modes of thinking.	0	1	2	3	4
18)	There was a high proportion of student talk and a significant amount of it occurred between and among students.	0	1	2	3	4
19)	Student questions and comments often determined the focus and direction of classroom discourse.	0	1	2	3	4
20)	`There was a climate of respect for what others had to say	0	1	2	3	4

Student/Teacher Relationships

21)	Active participation of students was encouraged and valued.	0	1	2	3	4
22)	Students were encouraged to generate conjectures, alternative solutions strategies, and ways of interpreting evidence.	0	1	2	3	4
23)	In general the teacher was patient with students.	0	1	2	3	4
24)	The teacher acted as a resource person, working to support and enhance student negotiations.	0	1	2	3	4
25)	The metaphor "teacher as listener" was very characteristic of this classroom.	0	1	2	3	4

*Adapted from Turley, J., Piburn, M., & Sawada, D. (2001).

Additional comments you may wish to make about this lesson.

APPENDIX E:

CORE AND PAPER INSTRUMENT

	IMPORTANT SCIENCE IDEAS /CONCEPTS				
	BIG IDEA “A”	**BIG IDEA “B”**	**BIG IDEA “C”**	***Researcher’s Comments***	***Researcher’s Comments***
#1. What you intend the students to learn about this idea?					
#2. Why it is important for students to know this					
#3. What else you know about this idea (that you don’t intend students to know yet).					
#4. Difficulties/limitations connected with teaching this idea					
#5. What knowledge about students’ thinking influences your teaching of this idea?					
#6. What are other factors that influence your teaching of this idea?					
#7. Describe how you will teach the main ideas in this lesson.					
#8. Why will you be using this procedure to teach these main ideas?					
#9. What are specific ways you will use to determine students’ understanding or confusion around this idea? Formative assessment Questions or activities to assess the concept Possible Student responses to activities Follow up or feedback					

to students response **Summative Assessment** **Quizzes, tests, or activities to assess the concept**					

*Code Number*___________________________*Date* ________________ *CoRe*__________ *and* *PaPer*___________

in regular type ***in italic type***

APPENDIX F:

PHYSICS TEACHING EFFICACY AND BELIEF INSTRUMENT (PTEBI)

An Instrument for Measuring Science Teaching Self-Efficacy STEBI-A (Enochs & Riggs, 1990, *modified*)

5 = STRONGLY AGREE   4 = AGREE   3 = UNCERTAIN   2 = DISAGREE   1 = STRONGLY DISAGREE

		SA A UN D SD
1.	When a student does better than usual in physics, it is often because the teacher exerted a little extra effort.	5 4 3 2 1
2.	I will continually find better ways to teach physics.	5 4 3 2 1
3.	Even if I try very hard, I will not teach physics as well as I will most subjects.	5 4 3 2 1
4.	When the physics grades of students improve, it is often due to their teacher having found a more effective teaching approach.	5 4 3 2 1
5.	I know the steps necessary to teach physics concepts effectively.	5 4 3 2 1
6.	I will not be very effective in monitoring physics experiments.	5 4 3 2 1
7.	If students are underachieving in physics, it is most likely due to ineffective physics teaching.	5 4 3 2 1
8.	I will generally teach physics ineffectively.	5 4 3 2 1
9.	The inadequacy of a student's physics background can be overcome by good teaching.	5 4 3 2 1
10.	The low physics achievement of students cannot generally be blamed on their teachers.	5 4 3 2 1
11.	When a low-achieving child progresses in physics, it is usually due to extra attention given by the teacher.	5 4 3 2 1
12.	I understand physics concepts well enough to be effective in teaching highs school physics.	5 4 3 2 1
13.	Increased effort in physics teaching produces little change in students' physics achievement.	5 4 3 2 1
14.	The teacher is generally responsible for the achievement of students in physics.	5 4 3 2 1
15.	Students' achievement in physics is directly related to their teacher's effectiveness in physics teaching.	5 4 3 2 1
16.	If parents comment that their child is showing more interest in physics, it is probably due to the child's teacher.	5 4 3 2 1

17.	I will find it difficult to explain to students why physics experiments work.	5 4 3 2 1
18.	I will typically be able to answer students' physics questions.	5 4 3 2 1
19.	I wonder if I will have the necessary skills to teach physics.	5 4 3 2 1
20.	Given a choice, I will not invite the principal to evaluate my physics teaching.	5 4 3 2 1
21.	When a student has difficulty understanding a physics concept, I will usually be at a loss as to how to help the student understand.	5 4 3 2 1
22.	When teaching physics, I will usually welcome student questions.	5 4 3 2 1
23.	I do not know what to do to turn students on to physics.	5 4 3 2 1

APPENDIX G:
NAPD TEACHERS' PCK RATING

Categories	#08 Margaret	#9 Curtis	#10 Retha	#11 Frank	#12 Jack	#13 Nancy	#14 Rebecca
CK							
1. Solid Content knowledge. *8	3	3	4	4	4	4	4
2. Use of Questions/Prior knowledge. *1	2	4	2	1	3	1	0
3. Connection to other ideas and real life. *10	2	3	2	4	3	4	2
4. Repertoire of teaching.	2	3	2	3	2	3	1
5. Innovative materials for teaching.	2	3	2	2	2	3	2
PK							
1. Transforms content knowledge to effective teaching.*5	1	4	1	2	2	3	2
2. Students' thinking and learning.	3	3	2	3	2	3	2
3. Knowledge of effective classroom assessment.	2	4	2	2	2	2	2
4. Activities address student needs or demands.	2	4	2	2	2	3	2
5. Internal or external factors that influence classroom instruction.	2	4	3	2	2	2	2
PCK							
1. Blends content and pedagogical knowledge	3	4	1	2	2	3	2
2. Displays confidence as a content specialist	2	3	4	4	4	4	4
3. Uses effective assessment	2	4	2	2	2	2	2
4. Instruction is students directed *19	2	3	1	1	2	2	0
5. Effect of professional development	2	3	0	1	0	2	0
Total	32	52	30	35	34	41	27