TRANSFORMATIVE PROFESSIONAL DEVELOPMENT: UNRAVELING THE COMPLEXITIES OF KNOWLEDGE, PRACTICE, AND BELIEFS

by

Janette Smith

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Janette Smith

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The following individuals read and discussed the dissertation submitted by student Janette Smith, and they evaluated her presentation and response to questions during the final oral examination. They found that the student passed the final oral examination.

Keith W. Thiede, Ph.D.	Co-Chair, Supervisory Committee
Michele Carney, Ph.D.	Co-Chair, Supervisory Committee
Joe Champion, Ph.D.	Member, Supervisory Committee
J. Eian Harm, Ed.D.	Member, Supervisory Committee

The final reading approval of the thesis was granted by Keith Thiede, Ph.D., Chair of the Supervisory Committee. The dissertation was approved for the Graduate College by John R. Pelton, Ph.D., Dean of the Graduate College.

DEDICATION

I dedicate this dissertation to my father, Roy Langton. My dad was an avid lover of science of all kinds. As a successful aerospace engineer for many years, he always inspired me to work hard and reach for the stars. Throughout this process, I often thought of him and gained the inspiration needed to get to the next step. I am hopeful that this dissertation will help to pass on a passion for science to teachers and their students.

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ABSTRACT

This study investigated the impact of a comprehensive professional development project focused on inquiry-based integrated lessons to improve the quality of science instruction for elementary teachers. Eleven teachers from three Northwest school districts participated in this quasi-experimental design study. A focus of the study was to investigate the intricate relationship between four components of a professional development model: the professional development intervention, teacher practice, student outcomes, and teachers' self-efficacy for science instruction. Five different measures were used both before and after the intervention: The Local Systemic Change Observation Protocol, a content knowledge assessment, a self-efficacy survey, a student content test, and a student science attitude survey. In an effort to triangulate data, a reflective digital journal was kept by each teacher throughout the project. Results indicate that teachers involved in the professional development intervention experienced statistically significant growth in lesson quality and self-efficacy for teaching science, thus impacting their practice and their students.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

PD	Professional Development
STEM	Science, Technology, Engineering, Mathematics
LSC	Local Systemic Change
AAAS	American Association for the Advancement of Science
STEBI	Science Teaching Efficacy Beliefs Instrument
mATSI	Modified Attitudes Toward Science Inventory
NGSS	Next Generation Science Standards
NSF	National Science Foundation
TIMSS	Trends in International Math and Science Study
NCLB	No Child Left Behind
RTOP	Reformed Teaching Observation Protocol
SCK	Science Content Knowledge
NSTA	National Science Teachers Association
NSES	National Science Education Standards
TPB	Theory of Planned Behavior
PSTE	Personal Science Teaching Efficacy
STOE	Science Teaching Outcome Expectancy
iSTEM	Integrated Science, Technology, Engineering, and Math
ANOVA	Analysis of Variance

CHAPTER ONE: INTRODUCTION

The decline of science instruction in elementary schools is a complicated phenomenon. Research indicates that a variety of factors have influenced the departure of science from the elementary school day (Blank, 2013; Dorph et al., 2011). Time to teach science has been one of the leading challenges for teachers in recent years due to the pressure to perform on high stakes tests in language arts and mathematics. Coupled with the introduction of Common Core curriculum in both areas, elementary teachers are feeling overwhelmed. Another issue influencing the lack of science teaching in elementary schools includes a lack of content knowledge, which directly influences confidence (Appleton, 2003; Yager, 2000).

Over the past few decades, numerous efforts have been attempted to ameliorate the problem of science instruction in elementary schools (National Research Council, 1996; American Assciation for the Advancement of Science , 1995). Consensus in the field of teacher education indicates that quality professional development may be one possible solution. Defining quality professional development is an area of education that has received much attention in recent years (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009; Fishman, Marx, Best, & Tal, 2003; Ingvarson, Meiers, & Beavis, 2005; Penuel, Fishman, Yamaguchi, & Gallagher, 2007; Sandholtz & Ringstaff, 2013). Research suggests that quality professional development that results in an increase of performance of students have several common features. Features such as duration, active participation, content knowledge, cohesion, feedback, collaboration, and an attention to how students learn are commonly referenced as quality indicators of professional development programs (Garet, Porter, Desimone, Birman, & Yoon, 2001; Birman, Desimone, Porter, & Garet, 2000; Desimone, Porter, Garet, Yoon, & Birman, 2002; Diaconu, Radigan, Suskavcevic, & Nichol, 2012; Ingvarson et al., 2005). Designing professional development with these elements in mind should be a priority for professional development providers.

Background of the Study

There exists a plethora of research identifying elements of effective professional development (Darling-Hammond et al., 2009; Fishman et al., 2003; Garet et al., 2001; Ingvarson et al., 2005; Penuel et al., 2007; Sandholtz & Ringstaff, 2013). The majority of this research has been large scale and has typically utilized self-report data from teachers. In these studies, teachers report common elements that contribute to perceived successful professional development experiences.

In addition to the elements of effective development, a common focus of more recent professional development studies has been on the components of the professional development (Desimone, 2009; Guskey, 2002). Relationships have been investigated between professional development, teacher practice, student outcomes, and self-efficacy; although few studies have investigated all four components simultaneously. Although the ultimate goal of most professional development interventions is to improve practice in order to increase student outcomes, and examination of the components of student outcomes is often left out of the literature. More comprehensive studies are needed that investigate the inter-relatedness of all four components of professional development models. In this study, these complex relationships are investigated while keeping the elements of effective professional development in mind.

In addition, this study attempts to use observational data instead of self-report data to measure science teaching practices. Concerning science practices specifically, Penuel et al. (2007) suggest that teachers of science are highly aware of the push for inquiry practices, and this in turn could impact their self-reporting of practices used to teach science.

Purpose of the Study

The purpose of this study was to examine the impact of a high quality professional development project focused on science instruction for elementary teachers. After researching quality PD models, a comprehensive professional development unit was developed incorporating essential elements of effective PD. Elements considered in the creation of the project included a focus on content knowledge, active participation, cohesion, duration, collaboration, and follow-up. Through this comprehensive professional development opportunity, teachers engaged in experiences designed to help improve the quality of their science instruction by increasing content knowledge, changing practice, and changing self-efficacy for science instruction. In addition, by trying out new practices, teachers experienced the effectiveness of these practices and will be more likely to adopt them permanently. The intricate relationships between these four essential components were also examined.

Research Questions

The following questions were used to guide this study:

- *Does participation in a comprehensive professional development intervention focused on an integrated science unit*

- *improve the quality of elementary science lessons?*
- *increase science content knowledge of elementary teachers?*
- *change teachers' sense of self-efficacy for teaching science?*

- *Do the students of the teachers who participated in the professional development project*
    - *show increased test scores over students of teachers who did not participate in professional development?*
    - *show increased engagement in science lessons over students who did not participate in professional development?*

Theoretical Framework

The theory guiding this study was developed by Guskey (2002). Guskey reports that the central goal of most professional development endeavors is to improve teacher practice, and as a result, improve student achievement. Guskey argues that many professional development opportunities lead to teachers trying out new practices in their classrooms, but only temporarily. Guskey believes that lasting change in practice will not occur unless teachers see a change in student outcomes. According to Guskey, once this change is perceived, teachers' attitudes and beliefs change, and the new practice is more likely to be permanently adopted (see Figure 1).

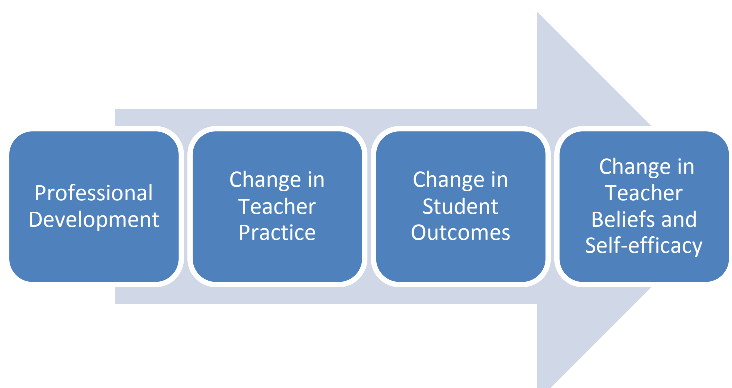

Figure 1. **Guskey's Theoretical Framework (Guskey, 2002)**

Although the notion that a connection exists between teacher practice, self-efficacy and student outcomes is not new, Guskey posits that the order of these components is important. Unique to Guskey's model is the idea that lasting change seldom occurs in teacher practice unless teachers have evidence of its success through student outcomes.

Nature of the Study

The selected design for this study was a mixed methods quasi-experimental design**.** Teachers were randomly assigned to either the control or treatment group. Student groups were determined based on the teacher to whom they were assigned. The independent variable in this study was the professional development intervention. The dependent variables include teacher content knowledge, teacher practice, student content knowledge, student engagement, and teacher self-efficacy. Several measures were used to assess each of these constructs both before and after the professional development. These variables are described in detail in the following section.

Description of Variables

Independent Variable

For this study, group (Treatment versus Control) was the independent variable, where the treatment group received professional development and the control group did not. Using research-based findings, six elements of effective professional development were included in the design of the intervention. Common elements of effective professional development included and also found in the literature include content knowledge, active participation, cohesion, collaboration, duration, and follow up (Ingvarson et al., 2005; Garet et al., 2001).

A more detailed and comprehensive description of the professional development intervention can be found in Chapter 3.

Dependent Variables

Using a theoretical framework developed by Guskey (2002), the idea that effective professional development can lead to a change in teachers' practice is central to this study (see Figure 1). The constructs of content knowledge, teacher practice, student outcomes, and a change in teachers' self-efficacy and beliefs will be examined using several measures that will be described in detail in Chapter 3. In this chapter, descriptions of each of these constructs are detailed below.

Content Knowledge

The construct of content knowledge was chosen as a focus for this study for several reasons. To begin, as reported in the literature, content knowledge influences teacher practice (Desimone, 2009). This is especially true for elementary science teachers due to a variety of factors (Nowicki, Sullivan-Watts, Shim, Young, & Pockalny, 2013). In addition, this identified element of successful professional development is easily measurable. Choosing constructs that are measurable is important to the study design. Defining content knowledge has become more complicated in recent years due to the identification of different types of content knowledge. For the purposes of this study, two specific types of content knowledge will be utilized: Science Content Knowledge and Pedagogical Content Knowledge. The science content knowledge refers to the knowledge of science subject matter. For this study, the specific knowledge for physical science subject matter will be measured at the fifth grade level. Pedagogical content knowledge refers to the content knowledge specific to the art of teaching that enables a teacher to effectively teach someone else about specific content (Shulman, 1987). Although pedagogical content knowledge will not be measured directly in this study, there was a strong focus on PCK for science instruction during the professional development intervention.

Lesson Quality

For the purposes of this study, four areas contribute to a high quality lesson: lesson design, lesson implementation, content knowledge, and classroom culture. Effective lesson design for science instruction includes providing opportunities for students to investigate or explore concepts, ideally through hands-on experiences (Appleton, 2003). A well designed lesson is organized, incorporates opportunities for students to work collaboratively, makes good use of resources, accounts for different learning styles, allows time for sense-making, and includes some sort of wrap up or closure (Banilower et al., 2013). Lesson implementation refers to teacher confidence, pacing, management skills, questioning strategies, and the ability to adjust to student needs (Banilower et al., 2013). Content knowledge, as discussed previously, refers to both the science content knowledge and the pedagogical content knowledge involved in teaching science. Within this context, teachers displaying high content knowledge should also be able to make connections to other content areas, as well as engage students intellectually at their varying levels (Banilower et al., 2013). Finally, classroom culture also indicates a level of quality for science instruction. Teachers displaying a high level of classroom culture encourage active participation from their students. They also display and foster a high level of respect within the classroom, encourage collaboration, questioning, and intellectual rigor (Banilower et al., 2013).

Student Outcomes

Student outcomes can take different forms. Measurable outcomes are common in the educational arena and include student achievement measures. Another form of student outcome that is often overlooked is the affective outcomes such as student engagement. Student engagement can play a pivotal role in a child's success in school (Klem & Connell, 2004).

Self-Efficacy

One widely accepted definition of self-efficacy comes from Bandura (1997): "…beliefs in one's capabilities to organize and execute the course of action required to produce given attainments." In the context of teaching, this construct refers to the beliefs teachers hold about their own abilities to deliver instruction effectively. Within the construct of self-efficacy, two different categories of self-efficacy have been identified (Bandura, 1997). The first is self-efficacy expectancy, and refers to beliefs of one's abilities to complete a specific task. Within the context of this study, this refers to a teacher's confidence to use a specific teaching practice. The second category of self-efficacy is outcome expectancy. Outcome expectancy is the belief that a specific behavior will produce a specific result (Bandura, 1997). Within this category, people may hold beliefs that external factors affect a specific outcome. In the educational setting these factors may include demographic information such as race, or social economic status.

Definitions

Content Knowledge: Within the educational community, this definition has become complicated as several specific components of content knowledge have been identified. For the purposed of this study, the following two definitions will be used:

Science Content Knowledge: Knowledge of science subject matter.

Pedagogical Content Knowledge: Content knowledge specific to the art of teaching that enables a teacher to effectively teach someone else about specific content (Shulman, 1987).

Active Participation: The involvement of teachers in planning, discussion and practice during professional development (Garet et al., 2001).

Collaboration: The process of working within a group to achieve a common goal.

Duration: Both the number of contact hours and the time span that the professional development covers (Desimone, 2009; Garet et al., 2001).

Cohesiveness: How well teachers perceive that the professional development aligns their goals and other external factors such as standards and testing (Penuel et al., 2007).

Follow Up: The ongoing support teachers receive after the professional development experience (Guskey, 2002).

Self-Efficacy: Beliefs in one's own abilities to execute and achieve a specific goal (Bandura, 1997).

Student Outcomes: Measures of a change in student achievement or student affect.

Inquiry: One of the most widely accepted definitions of inquiry is from the *National Science Education Standards (*NSES*)* (National Research Council, 1996). The NSES defines inquiry as follows: "Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating results. Inquiry requires identifications of assumptions, use of critical and logical thinking, and consideration of alternative explanations" (National Research Council, 1996).

Authentic Science: Authentic science is commonly conceived as the practices real scientists engage in to answer specific science questions.

Integrated STEM: An approach to teaching and learning that combines the content and skills of science, technology, engineering and math. Several types of integration are indicated in the literature.

Assumptions

The assumptions for this study include assumptions for each of the instruments used to collect data. It is assumed that the content knowledge accurately assessed the content knowledge levels of the teachers and students in the area of physical science. In addition, the self-efficacy survey is believed to give an accurate score for teachers' self-efficacy for teaching science. Due to the self-report nature of the survey, we will assume that teachers selected choices that best described their feelings, attitudes, and beliefs. Finally, we will assume that the lessons observed for later video analysis were what the teachers considered to be their best lessons. This assumption is important in order to support the need for only one video of each teacher both before and after the intervention.

Delimitations

Several delimitations are present in this study. First, the duration and context may narrow the generalizability of findings specifically to 5^{th} grade teachers teaching a specific unit. However the choice to narrow the focus stems from the research supporting effective professional development elements of cohesion and collective participation. Professional development that is focused and meaningful to teachers is more likely to affect classroom instruction. By giving teachers specific activities, resources, and practices to use in classrooms that align to standards and curriculum, teachers will be encouraged to implement the new practices in their classrooms. Allowing teachers opportunities to collaborate with teachers of the same grade level and potentially the same schools will give teachers a sense of support while they implement new practices in their classrooms.

The researcher as professional development provider in this study is also a delimitation. The reason for this choice is due to the expert knowledge of the researcher in the area of elementary science. The researcher currently works with upper elementary teachers in a position at the university. This position has allowed the researcher to become very familiar with the specific curriculum and practices addressed in standards and district curriculum. In addition, the 15 years of experience as a fifth grade teacher allow the researcher to connect with teachers on an insider level. Additionally, the researcher has been previously involved in developing an integrated unit specific to integrated physical science for a summer institute.

Limitations

There are two main limitations to this study. First, the participant number was limited to 11. This was a direct limitation on the external validity of the study. However, due to the comprehensive nature of the study, the data collected may serve as evidence to help design similar larger scale studies.

Another limitation was the use of video to record science lessons. Video observations, although valuable, do not always capture a complete picture of classroom happenings. Camera angles, obstruction of camera view are just a few of several limitations to filming teachers. Due to the large number of videos needed for this study, this was the only feasible way to conduct the observations.

Significance

Science instruction in elementary schools is limited due to a conglomerate of issues. Central to this problem is the lack of preparation of elementary teachers to teach science. To ameliorate this problem, there is a desperate need to provide elementary teachers with content specific professional development. Although the literature is replete with studies identifying the elements of effective professional development, studies that include the complex intertwining of all components are limited. This study combines the identified effective elements of professional development with all four components of highly regarded professional development frameworks. Specifically, this study investigates the impacts professional development can have on teachers' content knowledge, practice, self-efficacy, as well as student outcomes.

The need to improve science education extends far from the walls of the classroom. The pressure to globally compete in the technological age has created a national push to increase STEM education in American classrooms. The Next Generation Science Standards (NGSS) have compiled a plethora of evidence that illuminates the urgency to improve STEM education in American classrooms (NGSS Lead States, 2013). Evidence such as a reduction in our economic edge in the international arena, including a shrinking of U.S. patents, and a diminishing of high-tech exports due to competition with such countries as China are highlighted. Other evidence includes the widening of the student achievement gap between U.S. students and other countries; specifically in the areas of science and math. According to the Program for International Assessment (PISA) the U.S. ranked 23rd in science and 30th in math on the 2012 test (Kelly, Nord, Jenkins, Chan, & Kastberg, 2013). In addition, careers requiring more science and math education have grown exponentially, and companies are having difficulty filling positions with skilled workers. The United States is losing its edge and improving STEM education is viewed as the answer to solving this dilemma. Through research, the most effective approaches to improving teacher practice can be effectively identified and duplicated in larger scale projects to make the most impact.

Summary

Improving science learning experiences of elementary students will require intentional and prescriptive interventions for educators. Professional developers would benefit from incorporating as many effective elements of professional development as possible when planning projects. Elements such as a focus on content knowledge, active participation, cohesion, collaboration, duration, and follow up are empirically supported as effective elements of successful professional development opportunities for teachers. Moreover, professional developers should consider the intricate relationship between professional development, a change in practice, and a change in self-efficacy. All of these components seem to impact lasting change in practice as well as student outcomes.

CHAPTER TWO: LITERATURE REVIEW

Introduction

The decline of science instruction in elementary schools is a complicated phenomenon. Research indicates that a variety of factors have influenced the departure of science from the elementary school day (Blank, 2013; Dorph et al., 2011). There are multiple influences on elementary teachers' engagement in science instruction. According to the National Survey of Science and Mathematics Education only 39% of elementary teachers surveyed felt well prepared to teach science, which contrasts starkly to the 81% of elementary teachers surveyed who felt well prepared to teach language arts, and 77% of elementary teachers surveyed who felt well prepared to teach math (Banilower et al., 2013). Thus, levels of preparation to teach science and the associated lack of confidence are substantial factors that are likely to influence how elementary teachers engage in science instruction.

Time to teach science has been another challenge for teachers in recent years due to the pressure to perform on high stakes tests in language arts and mathematics. Coupled with the introduction of common core curriculum in both of these areas, elementary teachers are feeling overwhelmed. Other issues that have influenced the lack of science teaching in elementary schools include a lack of content knowledge, which has been shown to directly influence confidence to teach science (Appleton, 2003; Yager, 2000). Many teachers lack confidence to teach science and therefore avoid teaching it altogether. Appleton (2003) reports that elementary teachers tend to have gaps in their content knowledge, which limits their motivation and engagement in teaching science. Appleton (2003) also found that those teachers who commonly use hands-on activities for teaching science, borrowed activities that worked from their teaching of other subjects. Thus, there is support for the notion that when teachers engage in science instruction, they tend to draw instructional activities from experience, which may or may not be aligned with the instruction needed to address best teaching practices.

Science Education Reform: A Historical Perspective

In order to understand the current trajectory of science education reform, it's important to consider the most recent history of science education reform efforts. The following section details the science reform initiatives of the past few decades, and helps set the stage for the current efforts to improve science education in American classrooms.

The Age of Crisis in science education came to a crescendo in 1983 with the publication of the infamous report, *A Nation at Risk* (United States National Commission on Excellence in Education , 1983*)*. Published by the National Commission on Excellence in Education, this report was highly publicized and politicized. The report outlined many deficiencies in high schools including a declining curriculum, calling the typical course offerings in high school a veritable "smorgasbord." The report also detailed the low expectations of high schools, including minimal homework, low graduation requirements, and limited time in school, just to mention a few. The report also detailed the poor preparation of teachers, and also referred to the shortage of qualified teachers in subject areas such as math and science (United States National Commission on Excellence in Education, 1983). Although the committee that published *A Nation at Risk* gave a deleterious portrait of the state of American schools, it failed to contribute any tangible solutions to the asserted problems. In response to this document, Richard Elmore (2004) noted, "…the report is clearer on diagnosis with no prescription" (Elmore, 2004; p. 213). *A Nation at Risk* spawned a renewed energy to improve science education in America. In 1985, Project 2061 was created by the American Association for the Advancement of Science (American Association for the Advancement of Science, 1995). The goal of this project was, and still is, to increase literacy in math, science, and technology. Project 2061 receives funding from the NSF, NOAA, NASA, and the U.S. Department of Education. This project develops curriculum materials, assessments, as well as offers professional development publications for teachers. Since its inception, Project 2061 has published many notable publications including *Science for All Americans* in 1989, and *Benchmarks for Science Literacy* in 1993 (American Assoiciation for the Advancement of Science, 1995).

Undoubtedly one of the most comprehensive science education reforms of the late 20th century was the creation of the National Science Education Standards in 1996. Published by the National Research Council, these standards emphasized inquiry and hands on learning experiences for students (National Research Council, 1996). Around the same time, the first Trends in International Math and Science Study data were published, revealing that the United States was lagging behind other countries in the areas of science and math (Beaton, 1996). As a direct response, the NSB Task force on Math and Science Achievement, often called the TIMSS Task force, was established (Schmidt & McKnight, 1995).

One of the biggest blows to science education in the U.S. was the aftermath of President Bush's reauthorization of the Elementary and Secondary Education Act, otherwise known as No Child Left Behind (No Child Left Behind Act of 2001, 2002). With a renewed focus on testing, specifically in math and language, science was moved to the back burner in most American classrooms (DeJarnette, 2012). The testing frenzy exhorted by pressures of making adequate yearly progress for NCLB steered teachers away from best practices in order to get desired results on standardized tests (Elmore, 2004). The performance-based accountability era was born.

Just as educators were catching their collective breath from the damaging effects of NCLB, a new report was published in 2007 by the National Academy of Sciences entitled, *Rising above the Gathering Storm* (Augustine, 2005). This report elicited an urgent call to improve science and technology education in order to compete in our increasingly global world. The four recommendations of this most recent report include increasing the American talent pool by improving math and science education, strengthening research, developing, recruiting and retaining top students, scientists and engineers, and positioning the United States at the top in world innovation.

Rising above the Gathering Storm spawned a plethora of current initiatives supporting science reform. A sense of urgency to increase the number of students pursuing science, technology, engineering and math (STEM) majors in colleges in order to supply the increased demand for STEM positions in industry has fueled programs sponsored by the federal government, corporations, and private interest groups (Obama, 2009). Recently President Obama launched *Change the Equation*, a non-profit with a goal of improving STEM education in American schools. Another similar program, *Educate to Innovate*, strives to move American students from the middle to the top of the international pack in science and math achievement by 2024. This year alone, these efforts have raised over 700 million dollars from private and corporate donations.

There have been many more initiatives, reports, recommendations and reform efforts than those detailed above. Reviewing this list does instill the sense of science education cycling in and out of favor throughout history. One could also argue that much of the policy and political involvement in reform in general has left our students in no better shape than before. This “policy churn” (Elmore, 2004, p.218), has been largely ineffective. It’s important to consider the missing pieces in the science reform effort. One notable absence is the investment in the training of teachers through quality professional development. In the most recent report from New Horizon Research, a report that compiles teacher survey data on math and science, only 59% of elementary teachers reported participating in some sort of professional development for science in the last 3 years (Banilower et al., 2013). Compared to middle and high school teachers where 82% and 85% reported this type of participation, there appears to be a need to increase these opportunities for elementary teachers.

Theoretical Framework

The ultimate goal of most educational reform efforts is to enhance performance and learning experiences of students through improved practice of teachers. Research indicates that this change is a complicated process (Desimone, 2009; Guskey, 2002). Classroom experiences for students are influenced by the practices teachers enact in the classroom. Research suggests that changing teacher practice involves an array of interconnected components (Loucks-Horsley & Matsumoto, 1999). Components such as beliefs and content knowledge can influence the practices teachers choose to use in their instruction. Considerations of these components are essential for development of successful professional development opportunities for educators. Several theoretical frameworks have been developed regarding professional development (Desimone, 2009; Guskey, 2002; Loucks-Horsley & Matsumoto, 1999). The chosen theory for this study was developed by Guskey (Guskey, 2002). Guskey reports that the central goal of most professional development endeavors is to improve teacher practice, and as a result, improve student achievement. Guskey argues that many professional development opportunities lead to teachers trying out new practices in their classrooms, but only temporarily. Guskey believes that lasting change in practice will not occur unless teachers see a change in student learning outcomes. According to Guskey, once this change is perceived, teachers attitudes and beliefs change, and the new practice is more likely to be permanently adopted (see Figure 2).

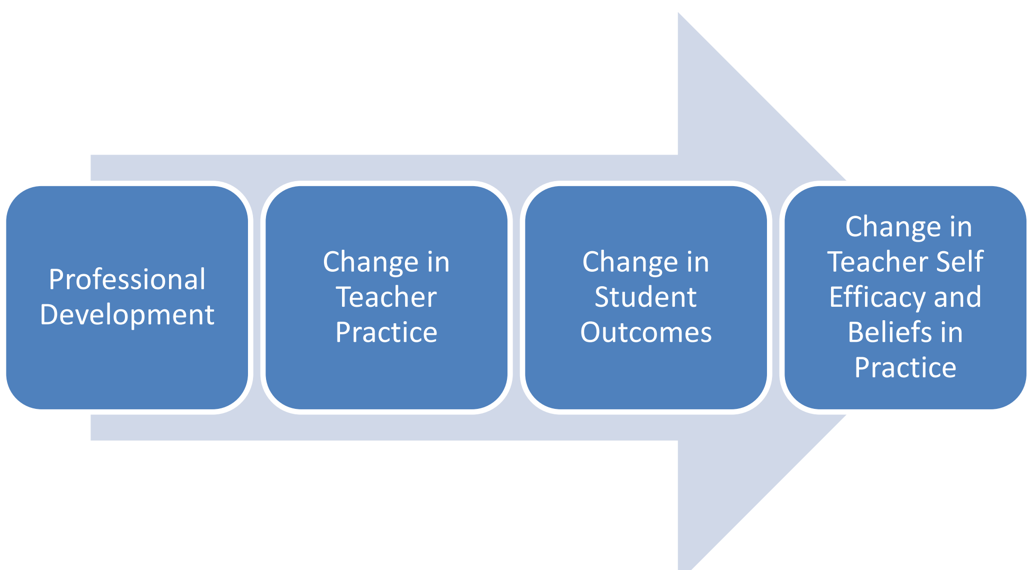

Figure 2. Guskey's Theoretical Framework (Guskey, 2002)

Guskey's theory posits that lasting change seldom occurs in teacher practice unless teachers have evidence of its success. The link between practice, student achievement, and teacher self-efficacy is not a new idea. What is unique about this model is the order of progression of these components. Guskey identifies three principles for professional development. First, recognize that change is difficult and takes time. Next, teachers need feedback on their students' learning. Finally, professional development should not end after the last workshop; teachers need follow up and continued support while they adjust to changing practice.

The organization of this literature review follows the order of Guskey's Theoretical Framework, beginning with professional development, moving to teacher practice, followed by student outcomes, and finally self-efficacy beliefs.

Professional Development

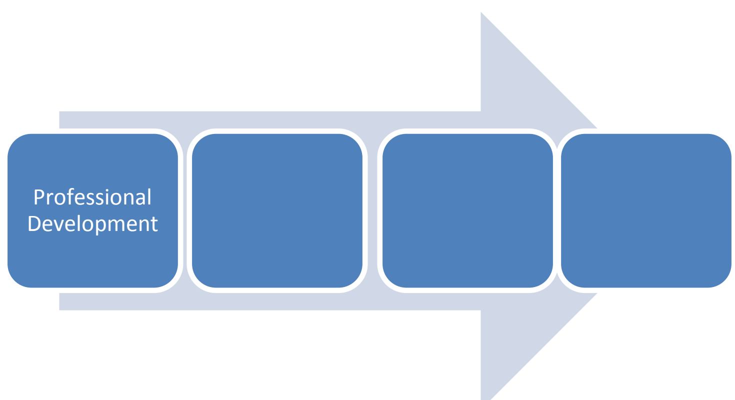

Figure 3. Professional Development

Defining Effective Professional Development

Consensus in the field of teacher education indicates that quality professional development may be the answer to improving science instruction in elementary classrooms (Birman et al., 2000; Borko, 2004). Defining quality professional development is an area of education that has received much attention in recent years. The logical goal of successful professional development for teachers is to improve practice in order to positively impact student achievement (Guskey, 2002; Penuel et al., 2007). There is a common conception in the educational community that changing practice of teachers is a complicated endeavor (Borko, 2004; Garet et al., 2001). Several models of the professional development process indicate that in order to change practice in teachers, several components must be considered, such as the professional development itself, teacher practice, and self-efficacy, and student outcomes. In the following section, an overview of literature related to the components of Guskey's theoretical framework for professional development is detailed.

Components of Professional Development

As previously detailed, the 4 components of Guskey's theoretical framework include professional development, a change in teacher practice, a change in student outcomes, and a change in teachers' self-efficacy (Guskey, 2002). Remarkably, few studies involve a comprehensive examination of these professional development elements. Several notable studies have chosen to investigate relationships between two components, such as Supovitz and Turner (2000), who narrowed the focus of their study to include professional development and its impact on inquiry teaching practices. In this 1997 study, survey data was collected from over 3000 teachers and 666 principals. Survey items attempted to investigate the relationship between professional development experiences and inquiry based teaching practices. A hierarchical linear modeling analysis showed several professional development experiences were significantly associated with inquiry based teaching practices. For instance professional development of at least 80 hours, principal supportiveness, classroom resource availability, content preparation, and teacher attitudes towards reform were all positively related to use of inquiry based teaching practices; whereas, professional development consisting of less than 39 hours, as well as demographic data including proportion of students on free and reduced lunch, school size, and male teachers were negatively related to inquiry based teaching practices (Supovitz & Turner, 2000).

Similarly, other studies have included different combinations of components from Guskey's model. Several studies have examined the relationship between content knowledge focused professional development and a change in teacher practice. One such study reported the status of a longitudinal study investigating the impacts of a science professional development program for elementary teachers of rural schools in California in year two of the study (Sandholtz & Ringstaff, 2013). Participants included 39 teachers from 16 different rural schools in northern California. Teachers participated in over 100 contact hours per year including an intensive summer institute. Teachers took tests of content knowledge at different points throughout the study. Analysis of results indicated a significant increase of teacher content knowledge in both the first and second years of the study. Changes in instructional practices were also noted in the results when comparing year one to year two, but not in all categories. The categories where significance was reported included utilizing real world contexts, using open-ended questions, encouraging students to consider alternative explanations, and integrating science with other subjects.

Other relationships between the components of Guskey's model include investigating the connection between teacher's self-efficacy beliefs and student achievement. Lumpe et al. (2012) administered a self-efficacy survey to collect data from 450 teachers both before and after an intensive 80 hour professional development summer workshop for science instruction. Results indicate that self-efficacy was a significant predictor of student achievement. Interesting to note was the year wait time for administering the final self-efficacy survey, suggesting that time to change beliefs may be a significant factor to consider within these frameworks (Lumpe et al., 2012).

In addition to studies focused on just a few components of Guskey's theoretical framework, a limited number of comprehensive studies have investigated all 4 components within one study. Ingvarson et al. (2005) surveyed 3250 teachers regarding their professional development experiences. Teachers were asked to rate the impact their experiences had on their knowledge, practice, sense of efficacy, and student learning. Findings from this study revealed key features of professional development that increase perceived effectiveness (Ingvarson et al., 2005). These features will be detailed in the following section.

Evidence of Effective Elements of Professional Development

Although the components included in professional development studies vary, there appears to be a consensus view of critical features of professional development necessary to create the most impact (Darling-Hammond et al., 2009; Fishman et al., 2003; Ingvarson et al., 2005; Penuel et al., 2007; Sandholtz & Ringstaff, 2013). Several large scale studies have attempted to identify the most effective professional development experiences. Throughout the literature, common features have been identified (Birman et al., 2000; Desimone et al., 2002; Diaconu et al., 2012; Ingvarson et al., 2005). In one comprehensive study, six factors of effective professional development were identified through a survey of 1000 teachers (Birman et al., 2000). Through an analysis of survey data combined with other research findings, the authors identified three structural features of effective professional development. These included form, duration, and participation. In addition, the researchers identified three core features. These included content focus, active learning, and coherence. Results from the surveys also indicate that professional development opportunities that include these desirable features are limited. Reasons indicated include cost, as well as time for districts to carefully plan effective professional development. In another widely cited article published using the same study data, findings relating to the essential features were included (Garet et al., 2001). Research supporting each of the key features was included in this article. Notable findings included that for collective participation having teachers from the same school and/or grade level is advantageous. Paying significant attention to the ways that students learn was important to include in the content feature. Included in active learning were opportunities to observe and be observed, opportunities to review student work, as well as presenting leading and writing. With regression analysis each of the six variables of effective professional development along with self-report data of teachers' perceptions of knowledge and skill enhancement and change in practice were correlated. Knowledge and skill were significantly impacted by a focus on content knowledge, active learning, and coherence. Similarly, change in teacher practice was significantly impacted by contact hours, a focus on content knowledge, coherence, and enhanced knowledge and skill (Garet et al., 2001).

In another longitudinal study, researchers collected survey data from more than 200 teachers over three years regarding professional development experiences (Desimone et al., 2002). Using findings from a previous national study, the researchers hoped to build on these findings. In the first study, the researchers identified three structural features of professional development: reform type, duration, and collective participation. They also identified three core features: active learning, coherence, and content focus. This study used self-report data from surveys administered at three different points in time: Fall 1997, spring 1998, and spring 1999. The goal was to evaluate the previously determined elements of professional development and their relationship to change in teacher practice over time. The sample was deliberately chosen to represent varying levels of schooling, with a total of 207 teachers' surveys used for final analysis. Teachers answered surveys with a specific professional development activity in mind. Questions included aspects of the six elements described above. In the area of content, three effective practices were identified: use of technology, use of higher order instructional methods and use of alternative assessment practices. These three elements are the focus of the analysis. Each element was analyzed separately using an HLM design. The grand summary indicates that when teachers experience technology related professional development, they are more likely to improve practice if they have collective participation as well as active learning. In addition, the results suggest that when professional development focuses on higher order thinking skills or alternative assessment methods, teachers benefit.

Elements of Effective Professional Development

Research suggests that quality professional development that results in an increase of performance of students have several common features.   Features such as a focus on content knowledge, active learning, duration, collaboration and cohesion have been linked to effective professional development in a variety of studies (Birman et al., 2000; Darling-Hammond et al., 2009; Desimone, 2009; Garet et al., 2001; Hill, 2007; Ingvarson et al., 2005). Other features such as follow-up are less commonly noted in the literature. In the following section, a summary of relevant literature for each of these features is detailed.

Content Knowledge

Content knowledge for education went through a dramatic overhaul in the mid 1980's (Ball, Thames, & Phelps, 2008). Shulman (1987) introduced several new domains for content knowledge for teachers, most notably, pedagogical content knowledge. This type of professional content knowledge specific to the art of teaching helped to lift the teaching profession to the same levels as other professions that require specific content knowledge (Ball et al., 2008). Shulman (1987) identified seven categories of teacher knowledge (see Figure 4). He specifically describes pedagogical content knowledge as a "special amalgam of content and pedagogy" (Shulman, 1987, p. 8) that is unique to the teaching profession.

- *Content knowledge*
- *General pedagogical knowledge*, with special reference to those broad principles and strategies of classroom management and organization tha tappear to transcend subject matter
- *Curriculum knowledge*, with particular grasp of the materials and programs that serve as "tools of the trade" for teachers
- *Pedagogical content knowledge*, that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding
- *Knowledge of learners and their characteristics*
- *Knowledge of educational contexts*, ranging from the workings of the group or classroom, the governance and financing of school districts, to the character of communities and cultures
- *Knowledge of educational ends, purposes, and values* and their philosophical and historical grounds

Figure 4. Shulman's Categories of Teacher Knowledge (Shulman, 1987, p. 8)

In more recent work in the area of content knowledge, Ball et al. (2008) have proposed an updated categorization of content knowledge that includes common content knowledge, specialized content knowledge, knowledge of content and students, knowledge of content and teaching, and knowledge of curriculum. With the intricate components of content knowledge in mind, professional development providers need to address the various aspects of content knowledge, paying specific attention to pedagogical content knowledge. Increasingly, content knowledge is becoming one of the most influential components of effective professional development, especially for elementary science teachers (Boyle, While, & Boyle, 2004).

Due to the limited number of science content courses required in elementary teacher preparation programs, many elementary teachers feel unprepared to teach science (Blank, 2013). Coupled with the limited number of professional development opportunities in elementary science, in-service elementary teachers do not have the support they need to become effective science educators (Boyle, Lamprianou, & Boyle, 2005). In one study, researchers investigated the science content knowledge of pre-service and in-service elementary teachers (Nowicki et al., 2013). After analyzing 81 video recorded inquiry based lessons, 74% of in-service teachers and 50% of pre-service teachers delivered accurate content. Positive correlations between content knowledge and several other factors were determined through multiple regression analysis. Higher content knowledge was significantly correlated with kit use, upper elementary grade level teachers, and a stronger preference for teaching science. Counter to other research findings, no correlations were found between the teachers' content knowledge and college science courses taken or college grade point averages. This study supports the use of unit specific kits in professional development settings to boost the science content knowledge of teachers (Nowicki et al., 2013).

A unique challenge specific to elementary science content is the fluidity of topics as districts adjust curriculum from year to year. Elementary teachers are typically responsible for three or four content topics in science, but it's not uncommon for topics to fluctuate between grade levels requiring teachers to have a wide array of science content knowledge over a variety of topics (Nowicki et al., 2013). In addition, with the pedagogical shift towards a more inquiry-based practice, the demand for a broader content knowledge base is more comprehensive due to the questioning nature of this practice (Fishman et al., 2003). Professional development programs that incorporate content knowledge as a component are more successful (Boyle et al., 2004). Several research findings indicate that what teachers learn in professional development is more important than how they learn it (Ingvarson et al., 2005). When content knowledge is a priority in professional development opportunities, elementary teachers are more likely to gain confidence and improve their practice (Blank, 2013).

Several studies have investigated the effects of professional development programs when content knowledge is prioritized. One recent study evaluated the effectiveness of the Rice Elementary Model Science Lab (REMSL) (Diaconu et al., 2012). This professional development opportunity for teachers of grades 2-5 was a comprehensive program designed to improve the quality of science instruction in Houston area schools. Components of the program included a focus on content knowledge in several science areas, pedagogy, with a specific focus on inquiry, and leadership skills. Participants received approximately 200 hours of professional development over the course of a school year. Data was collected via a variety of instruments. First, content knowledge data was collected through an online test developed by Rice University professors. In addition, an observation protocol (RTOP) was used to collect data on the use of inquiry based practices. Data was also collected on leadership skills through a survey. Results indicated that participation in REMSL significantly increased science content knowledge, and also significantly increased several leadership skills such as providing professional development to other teachers, attending science conferences, and applying for science grants.

Similarly, Diamond, Maerten-Rivera, Rohrer, and Lee (2014) investigated the relationship between 5th grade teachers' science content knowledge (SCK) and student achievement. One hundred twenty two 5th grade teachers from a large urban school district in a southeastern state were assigned to a treatment group where they participated in science professional development consisting of curricular materials, workshops and site support over one school year. Several measures were conducted and compared to a control group. Measures included a self-report science knowledge questionnaire, a science knowledge test, and classroom observations. The measures were administered both before and after the professional development intervention for both the treatment and control groups. In addition, student data was collected from a science standardized test. Professional development experience resulted in significantly higher science content knowledge scores for teachers as measured by test scores and the self-reported science knowledge survey. In addition, teachers' science content knowledge was shown to significantly impact science achievement outcomes for students as measured by a high-stakes science test. A HLM analysis showed predictors of increased science content knowledge of teachers were validated including years of experience. Interestingly, science courses prior to teaching were not a significant predictor of teachers' science content knowledge. In regards to student achievement, reading scores were found to be good predictors of science achievement.

Another recent study linking increased content knowledge to student achievement investigated the impacts of three varying science professional development interventions on teachers' content knowledge and student achievement (Heller, Daehler, Wong, Shinohara, & Miratrix, 2012). Although each of the three interventions had similar content components, the focuses of each varied, in the hopes of teasing out more specific effective approaches of increasing teachers' science content knowledge, and thus increasing student outcomes. Incorporating research supported features of effective professional development such as a focus on content knowledge, collaboration, duration, cohesion, and active participation, the researchers designed three specific professional development programs: *Teaching Cases*, where teachers studied written cases of classroom practice, *Looking at Student Work*, where teachers frequently analyzed their own students' work, and *Metacognitive Analysis*, where teachers focused on their own teaching through reflection. All three interventions focused on a specific 4th grade electricity unit, thus 4th grade teachers from a wide variety of school districts were invited to participate in the study. When compared to the control group, significant increases of content knowledge for both teachers and students in each of the three treatment groups were reported. When comparing the different treatment groups to each other, *Teaching Cases* participants were the only group to have significantly higher scores than the control group on the written justification portion of the science content test in the follow up year. Likewise, students of teachers in the *Looking at Student Work* group were the only students to increase their written justifications in the follow up year. Findings of this study suggest that professional development that integrates content learning with analysis of student work as well as reflective practice can significantly impact teachers' science content knowledge as well as increase student's science content knowledge (Heller et al., 2012).

Active Participation

Another feature of effective professional development consistently identified in the literature is active participation, sometimes referred to as active learning (Garet et al., 2001; Ingvarson et al., 2005; Penuel et al., 2007). Active participation has been defined as the involvement of teachers in planning, discussion and practice (Garet et al., 2001). Active participation formats vary, but elementary science teachers need more hands-on, inquiry based experiences in order to change practice (Penuel et al., 2007; Boyle et al., 2004). Inquiry-based instruction in particular may be a more difficult practice to master compared to other instructional practices, resulting in the need for more active participation and the need for a longer duration of professional development (Supovitz & Turner, 2000). Teachers experiences throughout their own education tend to influence the way they teach (Bencze & Hodson, 1999). Since many teachers grew up in an era of expository learning through textbooks it is important to offer opportunities to learn science concepts with a more constructivist approach (Penuel et al., 2007).

In one study highlighting the effectiveness of including active participation in professional development, teachers participated in a professional development project focused on inquiry based instruction at two levels (Shepardson & Harbor, 2004). The level 1 participants received training through a 4 week summer institute led by university faculty and graduate students. The core theoretical framework of this professional development was to engage teachers as learners in order for teachers to construct their own knowledge of inquiry learning. This active participation component was the driving force of the study. The level 2 participants were teachers that were trained by the level 1 participants. This "train the trainer" model was a key design component of the study. Results from the study indicate that the level 1 teachers experienced a significant change in practice (Shepardson & Harbor, 2004). For the level two participants, effects varied depending on the type of delivery of professional development administered by the level 1 teachers. Not surprisingly, 100% of level 2 teachers who received the active participation approach to learning the new practice changed their practice. This study validates the need to provide active participation opportunities for teachers learning new science practices, specifically the challenging practice of inquiry-based instruction.

Collaboration

Research indicates that collaboration increases the effectiveness of professional development (Birman et al., 2000; Desimone, 2009; Garet et al, 2001). Sometimes referred to as collective participation, collaboration of teachers from the same schools, the same grade levels, or the same subject areas increases the likelihood of active learning (Birman et al., 2000). In addition, collaboration allows teachers to work through the challenges of adopting new practices in a supportive environment; both within the professional development, but more importantly in the real setting of their school and classrooms (Desimone, 2009). The sense of community developed through collaborative professional development gives teachers a sense of belonging and support common in many professional learning communities (Birman et al., 2000).

Cohesion

Cohesion describes how well teachers perceive that the professional development aligns with their goals (Penuel et al., 2007). If teachers don't see the relevance in what they are learning in a professional development experience, the effectiveness of the professional development will be minimal. Teachers will not implement new practices that are not useful or aligned with the content and curriculum they are required to teach.

Duration

Two types of duration have been described in the literature. The first involves the number of contact hours. The other involves time span that the professional development covers; perhaps measured in weeks, semesters, or years (Ingvarson et al., 2005). Both seem to have an impact on effective professional development (Cotabish, Dailey, Hughes, & Robinson, 2011; Garet et al., 2001). Not surprisingly, research indicates that one or two day workshops do not have as much impact on practice and student learning as more intensive professional development (Boyle et al., 2004; Birman et al., 2000). Direct correlations have been found between professional development duration and teacher practice and student learning, suggesting that the more hours invested in professional development, the larger the impact will be on teacher practice and student learning (Boyle et al., 2004). Likewise, professional development endeavors that span longer time periods seem to make more pronounced impacts on teacher practice and student achievement (Birman et al., 2000). Although the duration hours necessary for changing teacher practice reported in the literature vary widely, there is consensus that practices such as inquiry-based instruction may require more hours than other practices (Supovitz & Turner, 2000).

Increasing the duration of professional development poses unique challenges. Time is money with professional development; the longer the professional development, the more expensive it becomes. In addition, getting teachers to commit to longer professional development projects is challenging due to the high demands of their jobs.

Follow Up

One of the most neglected elements of effective professional development is follow up (Ingvarson et al., 2005). In fact, much of the literature on effective professional development does not include the feature of follow up. Follow up refers to the ongoing support teachers receive after the professional development experience. Implementing change is a difficult process for teachers; without continued support after the initial training, many teachers abandon new practices (Guskey, 2002).

The following section moves on to the next component of Guskey's theoretical framework of the professional development process: teacher practice. Each section highlights a different empirically supported science practice. These practices should be strongly considered in the design process of professional development programs for science educators.

Changing Teacher Practice

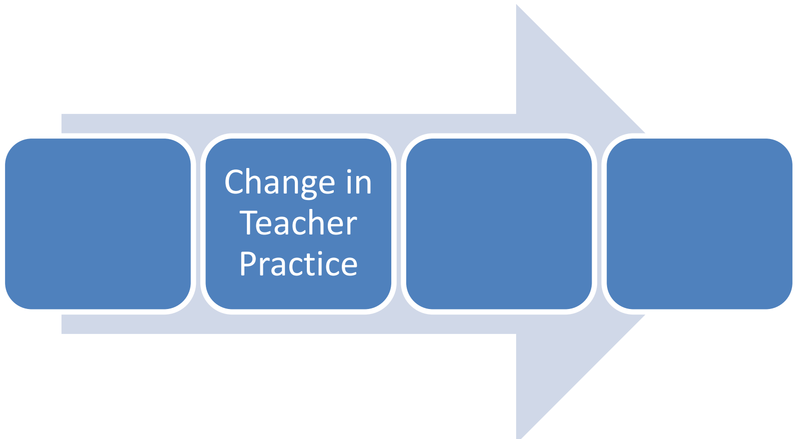

Figure 5. Changing teacher practice

<u>Pedagogical Shift in Science Instruction</u>

Over the past several decades, numerous efforts have been attempted to ameliorate science instruction in elementary schools (National Research Council, 1996). Recommendations from various respected councils and associations have issued a call to improve science instruction through an overhaul of pedagogical practices. In their position statement on elementary science, the NSTA states, "… inquiry science must be a basic in the daily curriculum of every elementary school student at every grade level" (NSTA, 2002). In support of this position, the NSTA statement also includes references to science reform and research, and the urgent need to engage students in science at young ages in order to develop problem-solving skills required in our scientific and technological world. Research supports the positive impacts early exposure to science experiences can have on students attitudes towards science, which in turn could impact their choices for majors in college and future career choices (Eshach & Fried, 2005).

Similarly, the National Science Education Standards advocated a science learning environment where students can learn about science by doing science (National Research

Council, 1996). Although these standards have been around for almost three decades, teachers have been reluctant to adopt new practices focused on authentic science, suggesting that professional development support for science educational practice has been limited and largely ineffective. Cochran-Smith and Lytle (1999) believe that although there is an abundance of empirical evidence supporting many best practices in education, the "wide-spread" practices used in classrooms are often due to an array of factors, including tradition, opinion, lore, inaccuracy, superstition, and delusion (Cochran-Smith & Lytle, 1999).

Recommended Practices for Teaching Science

Inquiry Learning

For the past several decades, inquiry-based learning has gained the top position as a preferred practice in the science education community. Advocated by notable organizations such as the National Teachers of Science Association, the National Research Council, and the American Association for the Advancement of Science, inquiry approaches to teaching and learning have been identified as paramount to teaching science effectively (National Research Council, 1996; NGSS Lead States, 2013). One of the most widely accepted definitions of inquiry is from the *National Science Education Standards (*NSES*)* (National Research Council, 1996). The NSES defines inquiry as follows: "Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating results. Inquiry requires identifications of assumptions, use of critical and logical thinking, and consideration of alternative explanations" (National Research Council, 1996).

The idea of inquiry as a tool for teaching and learning is not new. As early as 1913, early constructivist, John Dewey wrote about inquiry as a means to learn through doing (Dewey, 1913). Dewey was against traditional learning techniques such as recitation and memorization (Boydston, 1969). Dewey (1913) suggested that students needed to be given inquiry opportunities in learning in order to become better thinkers and problem solvers.

Inquiry learning supports aspects of both cognitive and social learning theory (Driscoll, 2005). Often viewed as interactional theory, and supported by the ideas of Bruner and Vygotsky, inquiry learning has many aspects of constructivism, mixed in with a social component. The main tenet of inquiry involves students exploring and investigating solutions to problems or questions. In an inquiry lesson, students often arrive at solutions and answers in different ways than other students investigating the same question. Students construct their own knowledge as they try to make sense of their experiences through experimentation. As a result, students are able to manage their own learning and gain a sense of ownership of their learning.

If done correctly, inquiry learning experiences can balance in that delicate zone of proximal development, thus pushing students to problem solve and come up with unique solutions to problems (Vygotsky, 1978). This stretch in their thinking can help form strong schematic connections to prior learning; thus allowing for greater retention of content, as well as an increased probability of transfer in future learning experiences.

Using carefully thought out probing questions throughout the inquiry process can help students reach and stay in this powerful zone.

The social aspect of inquiry learning is not to be discounted. Inquiry opportunities for students often involve cooperative opportunities for students. The social interaction involved in the problem solving process is vital to increased understanding of new concepts. According to Vygotsky, when working in groups or with partners, solutions must be co-constructed, and decision making throughout the learning process must be a joint effort (Driscoll, 2005).

A strong push for the inquiry method of science instruction has created additional challenges for elementary teachers (Fishman et al., 2003). With inquiry instructional techniques, teachers' content knowledge must be deeper and broader to accommodate the questioning component inherent in this type of practice (Fishman et al., 2003).

A variety of studies exist comparing inquiry-based instruction with traditional approaches, although not many studies have been conducted with elementary-aged students. For the most part, positive differences have been noted with the inquiry approach. Many researchers concede that the positive results of inquiry-based teaching are there, but may not be as stellar as many would have hoped (Anderson, 2002). However, more striking results have been noted with students who have learning difficulties (Scruggs, Mastropieri, Bakken, & Brigham, 1993). Current research seems to be moving away from the question of whether inquiry is an effective technique to implementation of the technique itself (Anderson, 2002).

Several studies on inquiry learning effectiveness have been conducted at the college level. In one study, freshmen participating in a biology lab were put into two groups. Group 1 received instruction in the more scripted lab approach, while Group 2 received an inquiry-based experience. The inquiry-based group scored 6% higher on a content exam at the end of the semester (Leonard, 1983).

Several meta-analyses that compare different teaching strategies and their impact on student achievement have been conducted. In one such analysis, 61 studies spanning a 24 year period were analyzed for effect size of eight specific teaching strategies, including inquiry. The effect size for inquiry–based teaching was .65, indicating a moderate to high effect on student achievement (Schroeder, Scott, Tolson, Huang, & Lee, 2007). In a more recent meta-analysis, with an admittedly small sample size due to few studies using true inquiry, guided inquiry lessons had larger effects on student achievement than student-centered learning (Furtak, Seidel, Iverson, & Briggs, 2009).

Another study supporting inquiry involved a three-year study in Detroit public schools (Marx et al., 2004). In partnership with the University of Michigan, inquiry units were developed for middle school students. Teachers were trained to teach using the inquiry method, and then taught the units to approximately 8,000 students over three years. Pre and posttest data on content and process were analyzed using t-tests and showed statistically significant effect size gains over the three years. For one unit on air, effect size gains ranged from.55 in Year 1, 1.25 in Year 2, and 1.84 in Year 3 of the study. Although this study did not compare inquiry to traditional methods, the evidence of the effectiveness of this practice is highly evident (Marx et al., 2004).

Although empirical evidence supporting the best practice of inquiry learning to teach science is evident throughout the literature, there still remains a significant divide between research and classroom practice, specifically in elementary classrooms. In order to bridge this gap, it is imperative that professional development specialists provide opportunities for teachers to engage in inquiry in order to construct their own understandings of this practice. Through a constructivist approach, teachers will see the value of inquiry learning and in turn provide similar experiences for their students.

Authentic Science Practices

Related to inquiry, the idea of authentic science has gained much attention in recent years. Authentic science is commonly conceived as the practices real scientists engage in to answer specific science questions. Most recently, with the development of the Next Generation Science Standards (NGSS), including essential practices aligned to the idea of authentic science has been a central component of new standards (NGSS Lead States, 2013). Placing a priority on the practices, and giving teachers the tools to help their students engage in these practices, is essential for the successful reform of science education. The eight recommended practices (see Figure 6) of the NGSS were developed by 18 experts from STEM fields (NGSS Lead States, 2013). The goal of the practices is for teachers to provide opportunities for students to engage in authentic scientific investigations as well as learn the skills required to perform such investigations. Since the NGSS also has engineering standards interwoven throughout all grades, some descriptions of practices pertain to the engineering aspects of science. Placing a priority on best practices for both students and teachers is a key component of any reform effort. As with any reform effort, the ultimate goal is to increase the performance of students. Recent research has shown that focusing on instructional practice results in learning gains for students (Elmore, 2004).

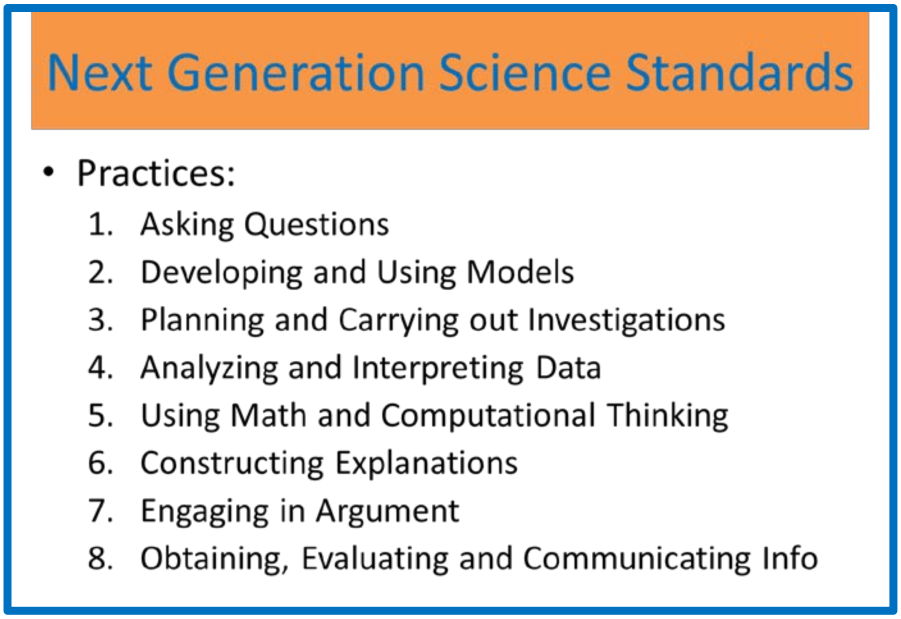

Figure 6. 8 Practices of the Next Generation Science Standards

Integrated STEM

STEM education has gained a tremendous amount of attention in the political arena in the past decade (DeJarnette, 2012; Herschbach, 2011). The pressure to globally compete in the technological age has created a national push to increase STEM education in American classrooms. The NGSS has compiled a plethora of evidence that illuminates the urgency to improve STEM education in American classrooms (NGSS Lead States, 2013). Evidence such as a reduction in our economic edge in the international arena, including a shrinking of U.S. patents, and a diminishing of high-tech exports due to competition with such countries as China are highlighted. Other evidence includes the widening of the student achievement gap between U.S. students and other countries. According to the Program for International Assessment (PISA) the U.S. ranked 23^{rd} in science and 30^{th} in math on the 2012 test (Kelly et al., 2013). In addition, careers requiring more science and math education have grown exponentially, and companies are having difficulty filling positions with skilled workers. The United States is losing its edge, and a push for STEM education is viewed as the answer to solving this dilemma.

The practice of integrating curriculum is not a novel idea. As early as the 1940's, thematic teaching incorporating math into science was termed "the core curriculum" (Aikin, 1942; Mickelson, 1957). A few studies evaluating the effectiveness of the core curriculum found that students within this group performed slightly better than students who learned in more traditional classrooms. In addition, findings indicate that students involved in core curriculums develop some affective attributes above their traditional counterparts. Attributes such as social awareness and social adjustment have been indicated in noteworthy studies (Mickelson, 1957).

Since the 1940's an interest in integrated curriculum has waxed and waned. Most recently, mainly due to societal needs and global competition, integration is making a comeback in classrooms, and consequently the literature. According to Beane (1996), new discoveries about how students learn have also rekindled an interest in integration. Student learning has traditionally been fragmented by subject, but research on how students learn indicates that a more connected approach to learning is more effective (Beane, 1996). Beane (1995) notes that traditional curriculum delivery is disconnected and makes no sense to many students. When dealing with real life problems, students will not ask which part is math and which part is science. Beane (1995) describes this separation of subjects approach as irrelevant and this separation will essentially create a "deadening effect" (Beane, 1995, p. 618) for student engagement to learn.

In the early 1990's, Donna Berlin (1991) compiled an extensive bibliography of research in the area of integration of science and mathematics teaching and learning.

Five hundred fifty five sources, spanning from 1901-1991, were cited in this bibliography, and later categorized into five sections including curriculum, instruction, research, curriculum-instruction, and curriculum-evaluation (Berlin, 1991). The purpose of this document was and continues to be a resource for teachers, curriculum developers and researchers. Findings from this compilation included a highly variable definition of integration, a lack of research on integration, and a need for assessments that measure achievement across math and science simultaneously (Berlin, 1991).

Within the literature defining integration has been a topic of much debate (Czerniak, Weber, Sandmann, & Ahern, 1999; Huntley, 1998; Pang & Good, 2000). In an attempt to answer this question, one meta-analysis reviewed 31 studies and categorized them into five different workable definitions (Hurley, 2001). Using a qualitative approach, the five categories of integration developed are ordered from least to greatest in terms of integration level (see Figure 7).

1. *Sequenced*: Science and mathematics are planned and taught sequentially with one preceding the other.
2. *Parallel*: Science and mathematics are planned and taught simultaneously through parallel concepts.
3. *Partial*: Science and mathematics are taught partially together and partially as separate disciplines in the same classes.
4. *Enhanced*: Either science or mathematics is the major discipline of instruction, with the other discipline apparent throughout the instruction.
5. *Total*: Science and mathematics are taught together in intended equality.

Figure 7. Categories of Integration (Hurley, 2001)

Once categories were assigned to each of the 31 studies, effect sizes for student achievement in math and science from each study were analyzed and category effect sizes were determined using Cohen's d . Findings indicate that benefits to math achievement scores were very small with the exception of the sequenced category (effect size of .85) where math is essentially taught independently. For science achievement, the highest effect size was .66 for enhanced integration. Next was sequenced with an effect size of .34, followed by partial with an effect size of .22. Like math achievement, the parallel integrated studies produced a negative effect size of -.09. This meta-analysis supports integrating math into science lessons as a means to increase science achievement (Hurley, 2001).

In another study with contrasting results, researchers investigated the impact integration of math into science class had on math achievement scores (Judson & Sawada, 2000). Eighth grade students participated in a quasi-experimental design project where 26 students were assigned to the control group, and 27 students were assigned to the treatment group for a three week unit. Treatment group students used graphing calculators and probes to perform statistical analyses within their science course. Students were given open-ended problems related to the genetics unit that required data collection and analysis. Decisions regarding appropriate statistical methods and representations were left open to the students. The control group students received "business as usual" instruction on statistics within their mathematics class. Science instruction was also limited to science content in the control groups' science class. Using a chi-square, statistically different grade distributions were noted between the treatment and control groups, where $\chi^2(4, N=53) = 16.92, p<.005$. The treatment group reported 21

A’s and B’s on the statistics test, while the control group only reported 9 (Judson & Sawada, 2000).

Other studies empirically support the integration of math and science. One such program developed by the Mid-California Science Improvement Program (MCSIP) supported teachers in the development of original thematic units that integrate all subjects around a central science theme (Greene, 1991). With unit development workshops through a summer institute, as well as continued support throughout the year, teachers taught the required curriculum through a year-long thematic unit. Evaluation of the program has yielded many benefits. Students and teachers alike have enjoyed increased engagement, and achievement scores for students have increased. National Assessment of Educational Progress (NAEP) scores at the end of the second year produced statistically significant gains with 78 percent of student improving their scores (Greene, 1991).

Vars (1991) reported that in over 80 studies on integrated curriculum programs, students performed as well as or better than students in non-integrated settings in almost all cases. Likewise, Stevenson and Carr (1993) compiled a collection of studies in which middle school teachers took on the challenge of teaching middle schoolers thematically with integrated units. The qualitative nature of the study clearly indicates that teaching “through the walls” of different subject matter classrooms is beneficial to students and teachers (Stevenson & Carr, 1993).

One criticism of the integrated approach is that teachers are not adequately trained or prepared to integrate curriculum (Frykholm & Glasson, 2005). More professional development opportunities are needed to give teachers the pedagogical tools necessary for successful integration. Basista, Tomlin, Pennington, and Pugh (2001) conducted a study to investigate the impact of professional development for middle grades teachers with a focus on integration of math and science. After participating in an intensive four week summer institute focused on inquiry and integration of mathematics and science, teachers showed significant gains in applying science concepts and mathematical reasoning on post-tests. In addition, results from an institute questionnaire showed a significant increase in self-efficacy for teaching integrated math and science. Qualitative reflections from participating teachers were included in the study and indicate that participants experienced a profound increase in confidence for teaching with an integrated approach (Basista et al., 2001).

What's noticeably missing throughout the literature on teacher professional development is perhaps the most important component of Guskey's framework: student outcomes. In the following section, different categories of student outcomes are examined.

Change in Student Outcomes

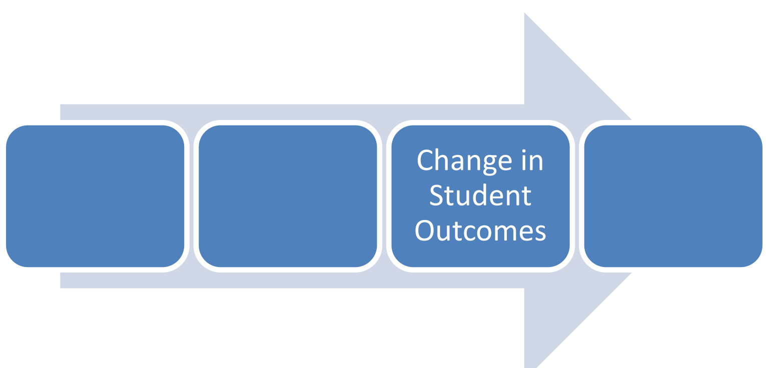

Figure 8. **Changing Student Outcomes**

Student Achievement

Although student achievement is the goal of almost all theoretical frameworks for professional development, very few studies report student achievement data. In one of the most widely cited articles on teacher professional development, researchers reviewed 1300 studies to investigate the impact of professional development on student achievement (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). Of these 1300 studies, only nine met the criteria of this meta-analysis. Of these nine studies, six reported significant effects on student achievement, and only two of those were science professional development (Marek & Methven, 1991; Sloan, 1993).

Marek and Methven (1991) researched the relationship between a professional development project focused on hands on laboratory experiences and student achievement. Sixteen teachers and 100 students participated in this study where teachers in the experimental group met five hours a day for four weeks and experienced a specific teaching practice called the learning cycle. This technique consisted of exploration and gathering of data, concept development, and concept application and expansion. Control group teachers who generally taught in an exposition style were matched with treatment group teachers. Teachers from the experimental group taught the content specific to their grade levels using the learning cycle method. Student data was collected on conservation of length, weight and liquid volumes both before and after the new practice was taught in the experimental classrooms. Students of the teachers in the experimental group scored significantly higher on posttests, indicating that the learning cycle practice positively impacted student achievement (Marek & Methven, 1991).

Moreover, student outcome measures can take many forms; some immediate while others require wait time. Immediate measures may take the form of teacher observations, student interactions and discussions and other forms of formative assessment (Fishman et al., 2003). Other measures preferred in the research community include standardized and normed assessments, as in achievement tests. Another unique challenge when measuring the effectiveness of professional development using an integrated STEM approach is the need for assessments that measure both areas simultaneously (Berlin, 1991).

Student Engagement

Although the focus on student outcomes is overwhelmingly on student achievement, student engagement should not be overlooked. Much of the literature on student engagement points to the impact student engagement has on achievement (Klem & Connell, 2004; Singh, Granville, & Dika, 2002). In relation to the context of this literature review, it's important to consider how student engagement can influence teacher practice and beliefs. Guskey (2002) believes that teachers need feedback from students in order to continue trying out new practices. Likewise, Fishman et al. (2003) support the notion that student feedback to teachers can take a cognitive or affective form; either way, this feedback helps shape teachers' beliefs and practices. Improved student achievement is motivating for teachers, but perhaps student engagement can also exhort teachers to press on with new practices. Much of the literature in the area of engagement is focused on the impact of teacher practice on student engagement. Literature addressing the impact of student engagement on teacher practice is virtually non-existent.

One study investigated the reciprocal relationship of teacher behavior and student engagement (Skinner & Belmont, 1993). One hundred forty four students in grades 3-5 and their 14 teachers participated in the study. Both students and teachers filled out questionnaires in both the fall 1988 and spring of 1989. Teachers filled out individual questionnaires of 11 items for each student with Likert scale items focused on four categories. Categories included affection, attunement, and dedication of resources such as time and energy, and dependability. Student surveys included items included perceptions of the teacher's involvement and support. In addition, student engagement surveys were administered to students along with teacher surveys of their perceptions of student engagement. Using intraconstruct correlations, significant correlations were found between teacher behavior and student engagement. The researchers note, that the issue of directionality of this relationship is still unclear; is there an influence of teacher behavior on engagement, or an influence of student engagement on teacher behavior (Skinner & Belmont, 1993)? Although this study examined the relationship between teacher behavior and student engagement, it would not be a stretch to consider that teacher practice and student engagement share the same reciprocal relationships.

To connect to the practices addressed in the previous section of this literature review, evidence supports the notion that students are more engaged and motivated when given the opportunities to participate in constructivist learning opportunities such as inquiry learning and integrated STEM (Stevenson & Carr, 1993). Thus, providing science professional development incorporating these practices, will likely result in the increased engagement of students. This increased engagement would in turn provide teachers with the necessary positive feedback to continue the new practices in their classrooms.

Finally, the relationship between a teacher and her students can play a reciprocal role in a variety of areas. Elementary students spend 6-7 hours a day with the same teacher. The bonds that form between teacher and student at the elementary level are strong and influential in many ways (Davis, 2001). It's not uncommon for young students to accidentally refer to their teacher as "mom." This nurturing, family-like relationship may help explain why evidence of student engagement can influence teacher practice. Teachers get excited when their own students are engaged in learning. When trying out new practices, if teachers receive positive feedback from students, this could provide the encouragement and motivation to continue the new practice. This also could impact the teacher's beliefs about the newly adopted practices, which will be discussed in the next section.

Teachers' Beliefs about Practice and Self Efficacy Beliefs

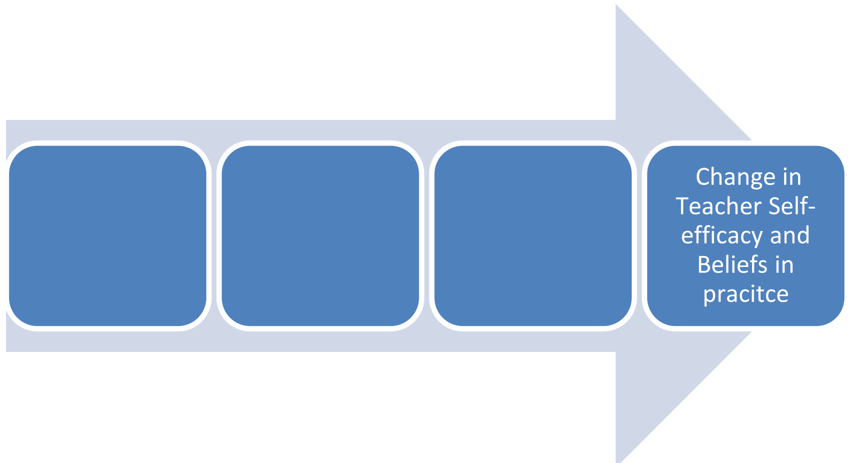

Figure 9. Changing Teacher Self-Efficacy and Beliefs in Practice

<u>Teachers' Beliefs about Practice</u>

In the educational arena, teacher beliefs are conceptualized in two different ways. First, teachers hold beliefs about the practices they choose to use in instruction. These beliefs are deeply rooted and difficult to change (Appleton, 2003). Teachers often teach in ways similar to the way they were taught which poses challenges as new practices are developed and introduced into the teaching profession (Bencze & Hodson, 1999). Specifically, the change from traditional approaches to teaching science content through lecture and textbook to the more hands on nature of inquiry is a difficult transition for many teachers who never experienced this type of learning themselves.

Teacher beliefs and values impact how they teach science (Levitt, 2002). Although many elementary teachers believe that science instruction should be student centered, many lack experience with inquiry-based instruction (Levitt, 2002; Thomson & Gregory, 2013). Thus, when presented with the expectation to teach using inquiry many elementary teachers may struggle or completely avoid teaching science. In addition to lack of experience, teachers reported time and science instructional materials as significantly constraining their ability to effectively implement a student centered science curriculum (Thomson & Gregory, 2013).

One theoretical framework cited in the literature that looks at this type of beliefs is Ajzen's Theory of Planned Behavior (TPB) (Ajzen, 1991). This theory has three main components: attitude toward a behavior, subjective norm, and perceived behavioral control (see Figure 10). The attitude toward a behavior includes beliefs about possible consequences that may occur if a specific behavior is performed. The subjective norm is the social aspect of the model and includes beliefs about what other people think about how a behavior should be carried out. Finally the perceived behavioral control includes beliefs about obstacles and resources that relate to the behavior. All three components combine to form a behavioral intent, which in turn lead to the way a behavior is carried out (Ajzen, 1991).

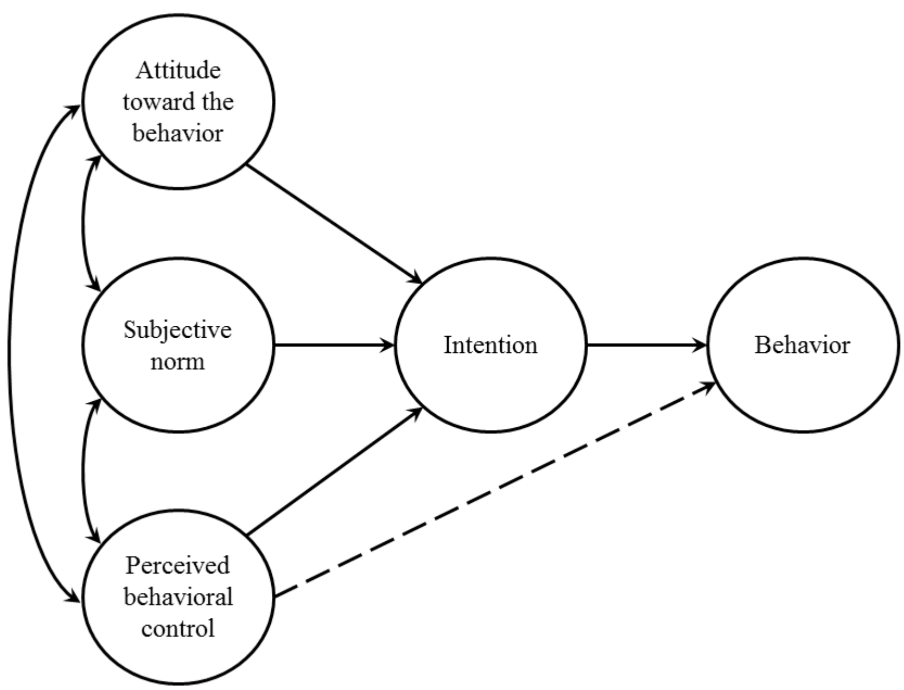

Figure 10. Ajzen's Theory of Planned Behavior

Several studies have operationalized Ajzen's Theory of Planned Behavior to measure changes in teacher beliefs as a result of professional development. In one study researchers examined teacher beliefs in regards to the implementation of science reform efforts (Haney & Czerniak, 1996). The purpose of this study was to identify belief factors that motivate change in teacher behavior. The study looked at four strands of the Ohio Competency-Based Science Model including science inquiry, scientific knowledge, conditions for learning science, and applications of science learning. A structured interview and a questionnaire were used to examine factors influencing teachers' intentions for implementing each of the four strands. Using Ajzen's Theory of Planned Behavior, results indicated that attitude toward the specific strand was the most influential predictor of the teachers' intent to implement the reform. Results from this study have strong implications for current and future science reform efforts.

In a more recent study, Milner, Snodergeld, Demir, Johnson, and Czerniak (2012) investigated the impact No Child Left Behind (NCLB) has had on elementary teachers' beliefs about teaching science. Initially, NCLB required testing of only mathematics and language arts, but in 2007 science was added to the list of testing requirements. The goal of researchers in this study was to compare teacher beliefs about science teaching before and after the testing requirement. Using a mixed methods approach, a questionnaire was developed that included both scaled statements and open ended questions and was administered to 502 teachers for the pretest, and 170 for the posttest. Using Ajzen's (1991) Theory of Planned Behavior, the results indicate that the teachers held positive beliefs of both attitude and subjective norm both before and after the NCLB science testing requirement. For perceived behavioral control, results were moderate and indicated teachers felt a lower level of confidence for specific control factors such as resources and time. Through analysis, researchers discovered that teachers' beliefs were influenced by their colleagues and principals, more so than federally mandated policy (Milner et al., 2012).

Teachers' Self-Efficacy Beliefs

Another important conception of beliefs within teaching is the beliefs teachers hold about their own abilities to deliver instruction effectively. These types of beliefs are referred to as self-efficacy. Self-efficacy is defined as, "…beliefs in one's capabilities to organize and execute the course of action required to produce given attainments" (Bandura, 1997). Bandura's social cognitive theory has been widely accepted as the grounding theory for teacher self-efficacy. Cognitive social theory separates beliefs into two distinct categories. Self-efficacy expectancy refers to beliefs of one's abilities to complete a specified task. In education, this may relate to a teachers confidence to use a specified teaching practice. Outcome expectancy is the belief that a specific behavior will result in a specific result. Within this construct, people hold beliefs that external factors may impact a specific outcome. In the educational setting, these factors might include social economic status or other demographic information (Bandura, 2001; Fitzgerald, Dawson, & Hackling, 2013).

Measuring self-efficacy of teachers poses some unique challenges. Riggs and Enochs (1990) have developed a widely used survey specifically designed to measure the self-efficacy of science teachers. The Science Teacher Efficacy Beliefs Instrument (STEBI) consists of two constructs. Thirteen items on the survey measure personal science teaching efficacy (PSTE), while 12 of survey items measure science teaching outcome expectancy (STOE) (Riggs & Enochs, 1990).

Several mitigating factors influence elementary teachers' self-efficacy for teaching science. Beginning with their pre-service experiences, elementary teachers are exposed to limited science content and methods courses. Coupled with the vast array of science topics the typical elementary teacher is required to teach in a school year, it's no wonder elementary teachers lack confidence to teach science and generally have a low self-efficacy for science instruction. Due to these circumstances many elementary teachers abandon teaching science altogether (Appleton, 2003).

In the context of Guskey's theoretical framework for professional development, teacher self-efficacy is perhaps the most complicated. Considerations for including this component when designing effective professional development programs are essential.

There exists a significant body of literature connecting teacher self-efficacy to teaching practice and student achievement. Lakshmanan, Heath, Perlmutter, and Elder (2011) conducted a longitudinal three-year study of the impacts a science professional development program had on teacher self-efficacy and teacher practice. Approximately 70 teachers per year of grades 5-8 volunteered to participate in the study over the three year span. The foci of the study included summer content courses that focused on inquiry-based practices followed by regular meetings in professional learning communities throughout the school year. Using the Science Teaching Efficacy Beliefs instrument (STEBI) and the Reformed Teaching Observation Protocol (RTOP), data was collected and analyzed using an HLM design. The STEBI test, by design, is broken down into two subscales representing two different constructs. Subscale 1 included 13 items that pertained to personal science teaching efficacy (PSTE). The remaining 12 item included items that measure teacher beliefs that student learning can be influenced by effective teaching (STOE). Results of the analysis showed a significant change in the PSTE portion of the STEBI, but not the STOE portion. Results from the RTOP indicated that the teachers experienced a positive improvement in the implementation of inquiry instructional practices. In addition, positive relationships between change in self-efficacy and change in the use of inquiry practices were noted, indicating that professional development can be an effective conduit for transforming teacher practice and beliefs (Lakshmanan et al., 2011).

In a similar mixed methods study, researchers investigated the impact of a science professional development program on teachers' sense of self-efficacy (Posnanski, 2002) . Like the Lakshmanan et al. (2011) study, the STEBI surveys were administered to 31 participants, teachers of grades K-6, both before and after the professional development intervention. Qualitative data was also collected via an open ended survey that required teachers to answer open-ended questions. The professional development program used a modified version of the Biological Sciences Curriculum Study (BSCS) unit entitled *Decisions in Teaching Elementary School Science*. A constructivist approach was used throughout the intervention where teachers actively participated in hands on learning experiences. Interestingly, techniques used by professional development providers aligned with Bandura's (1997) instructional strategies for changing self-efficacy beliefs. Strategies used included mastery experiences, vicarious experiences, verbal persuasion, and positive emotional tone. Results from this study indicated a significant change in the

PSTE portion of the STEBI. Although the STOE portion of the STEBI did not show significance, the scores still indicated an increase in self-efficacy (Posnanski, 2002).

In the international arena, the importance of considering teachers' self-efficacy beliefs for teaching when designing professional development has become a priority. A Chinese study investigated the impacts of a video-based science professional development opportunity for elementary school teachers (Sang et al., 2012). This study specifically investigated teachers' self-efficacy changes after participating in the project. A quasi-experimental design was used with 23 teachers assigned to the treatment group and 23 teachers assigned to the control group. Teachers in the treatment group participated in a 10 week video-based professional development project where science lessons of participants were video recorded and later used for reflection purposes. Two measures of teacher beliefs were used in this study both before and after the intervention. The first measure was the Teacher Beliefs Survey. This survey had two subscales; one for traditional teaching beliefs, and one for constructivist teaching beliefs. The STEBI was used to measure self-efficacy for teaching science. Significant differences were found on three of the four subtests between the experimental group and the control group. Differences were found on both subtests of the Teacher Beliefs Survey; the TTB and the CTB. For the STEBI, significant differences were found on the PSTE subtest, but not the STOE. Findings indicate that quality professional development does have the potential to change teacher's self- efficacy and in turn impact practice (Sang et al., 2012).

Due to the seemingly unfortunate climate of science at the elementary level, Australian researchers were prompted to highlight the self-efficacy of four effective elementary science teachers (Fitzgerald et al., 2013). This qualitative study incorporated classroom observation and semi-structured interviews to develop case studies. Themes were identified from the field notes and interview transcriptions including classroom environment, conceptual knowledge and procedural skills, teaching strategies and approaches, student-specific considerations, teacher-specific considerations, and context-specific considerations. Within each of these categories, sub themes of teacher beliefs were identified. Findings support the strong interconnectedness between practice and beliefs. In closing the researchers stated, “The beliefs held by the four teachers were strongly intertwined with their practice in an almost indivisible manner” (Fitzgerald et al., 2013, p. 1000).

It’s clear that teachers’ beliefs about practice as well as their self-efficacy play a powerful role in practice, and student achievement. Addressing this important component within professional development programs is essential in order to make lasting change in practice. Over the last few decades, much of the spotlight has been given to content knowledge within professional development programs. In recent years, more focus is being paid to teachers’ self-efficacy as researchers begin to understand the complex role this essential component plays in teacher change.

Summary

Designing professional development programs that work has become a complicated endeavor. Research surrounding effective professional development has resulted in identifying elements that seem to produce positive changes in teacher practice. Elements such as content knowledge, duration, active participation, collaboration, cohesion, and follow-up have been consensually identified as effective elements.

Although progress towards understanding how teachers adopt new practices through professional development has been made, there is still a need for further investigation. In regards to components of professional development, four basic components have been identified within the literature including the professional development itself, teacher practice, teacher beliefs, and student outcomes. The order these components seem to progress is up for debate (Desimone, 2009; Guskey, 2002; (Loucks-Horsley & Matsumoto, 1999). The majority of research studies on professional development typically investigate just two of the components of professional development. More comprehensive studies are needed that investigate all four components and their interconnected impact on science reform efforts.

One notable commonality within the literature is the self-report nature of the data collected. Although it can be argued that self-report data is just as reliable as observational data to measure practice (Mayer, 1999), the reliability of such measures may vary depending on content area. Concerning science practices specifically, Penuel et al. (2007) suggest that teachers of science are highly aware of the push for inquiry practices, and this in turn could impact their self-reporting of practices used to teach science. Many of the studies highlighted in this review list the self-report nature of the data as a limiting factor. This suggests that more authentic data, such as data collected via observation protocols, may give a more accurate account of teachers' practices when engaging in science instruction.

The critical need for science professional development for elementary teachers has reached a crescendo. Using empirically supported elements of professional development, combined with empirically supported best practices may be the most effective way to improve teacher practice, student outcomes, and teachers’ self-efficacy for STEM teaching.

CHAPTER 3: METHODOLOGY

Introduction

This study reports the results of the impact of a science professional development project on teacher content knowledge, teacher practice, teacher self-efficacy for science teaching, teacher beliefs in new practices, and student achievement and engagement. The timeline for this study was the spring semester of 2015. Teachers from three Northwest school districts participated in the study. The professional development experience occurred in seven three hour sessions approximately once a week. Teachers met after school at a university professional development facility centrally located to accommodate all participants.

Several measures were used in this study to collect data both before and after a professional development intervention. Specifically, these tools measured teacher lesson quality, teacher content knowledge, student content knowledge, student engagement, and teachers' self-efficacy for science instruction. In addition, reflective journals helped to triangulate findings from the surveys as well as indicate the teachers' changing beliefs in new practices throughout the intervention process.

Research Design and Rationale

This study was a mixed methods quasi-experimental design and investigated the following questions:

- *Does participation in a comprehensive professional development intervention focused on an integrated science unit*
    - *improve the quality of elementary science lessons?*
    - *increase science content knowledge of elementary teachers?*

  - *change teachers' sense of self-efficacy for teaching science?*

- *Do the students of the teachers who participated in the professional development project*
  - *show increased test scores over students of teachers who did not participate in professional development?*
  - *show increased engagement in science lessons over students who did not participate in professional development?*

Eleven participants were randomly assigned to a treatment group or a control group, resulting in six participants assigned to the treatment group, and five teachers assigned to the control group. The treatment group participated in 21 hours of professional development focused on the creation of an integrated physical science unit. Control group teachers taught the same content using their current instructional approach. The purpose of this study was to investigate the impact of a carefully designed professional development project. Impacts on teacher practice, content knowledge, teacher self-efficacy for science instruction, and student outcomes were measured. In addition, reflective journals of treatment group teachers supplemented the study with a small qualitative component to enhance and support the quantitative data of the study.

Since teachers self-selected to participate in this project prior to group assignment, the expectation is that teachers in the control and experimental groups will be similar. For this reason, Analysis of Variance was used for each of the measures.

In evaluating the qualitative data from reflective journals, open coding was used with post-hoc themes. Emergent themes were compared to Guskey's components for professional development, and connected to outcomes of the quantitative measures.

Methodology

Participants

The population for this study includes all public school upper elementary teachers in the United States who teach science (grades 3-5), as well as all public school upper elementary students (grades 3-5) in the United States. The sample of the population in this study includes 11 fifth grade teachers from three school districts in the Northwestern United States, as well as the students of these 11 teachers (see Table 1).

Table 1
Participants

Table 1
Participants

Treatment Group	Years Experience	Education
Amy	16	BA, MA, Sp. Ed/Curriculum
Mark	13	BA, MA, Ed Tech
Melissa	13	BA, MA, Sp. Ed/Curriculum
Beth	15	BA, MA, Curriculum
Tom	8	BA, MA, Ed Tech
Sarah	14	BA, MA, Curriculum
Control Group		
Michelle	33	BA, MA, Curriculum
Susan	10	BA, MA, Curriculum
Tammy	15	BS, MA, Curriculum
Claire	16	BA
Nancy	20	BA, MA, Administration

*Names of participants are pseudonyms.

Sampling Procedures

The teacher participants in this study self-selected to participate in this study. Teachers were randomly assigned to either the treatment or the control group. If a teacher was selected for a specific group that has a same school colleague participating in the study, the colleague was automatically assigned to the same group. This was necessary to prevent contamination of the control group by the treatment group, and also created opportunities for collaboration. Students were assigned to either the control or treatment group based on the placement of their teachers.

Recruitment of Participants

Initial communication was sent via an email to the principals of schools within three school districts (see appendix A). The email gave a brief overview of the project with an attached flyer to be distributed to the fifth grade teachers at each school. Teachers who were interested were directed to contact the researcher directly via email.

Teachers were debriefed in a face to face meeting prior to the study in February, 2015. At this time, informed consent was provided in a paper copy. Initial data was collected for the content knowledge test and the self-efficacy survey at this meeting. Other data collected included demographic information such as age, degrees held, and years of experience. Scheduling for the initial video recorded science lessons concluded the meeting.

Description of Treatment

With elements of effective professional development in mind (Garet et al., 2001), a professional development unit was developed by the researcher with a specific focus on the fifth grade physical science standards and curriculum. The following sections details each identified element of effective development and how each element was infused into the professional development intervention. Table 2 details the topics and activities for each week.

Table 2
Overview of Professional Development Activities

Week	Topics	Representative Activities/Inquiries
1	Elements, Atoms	Lego Molecules, Building Atom Models
2	States of Matter	Movin' Molecules, Sublimation Experiment, Oobleck
3	Properties of Matter	Separating Mixtures, Polymer Lab, Brown Sugar Lab
4	Physical Changes	M &M lab, Crystal Crush, Density Columns
5	Chemical Change	Film Canister Rockets, Controlling a Chemical Reaction
6	Chemical Change	Chemistry in a Bag, Mystery Powders
7	Follow Up	Sharing Implementation efforts; adjusting activities

Cohesion

As discussed in the literature section of this paper, cohesion refers to how well the teachers perceive the professional development aligns with their goals. In order to make this study as relevant as possible, the researcher consulted the science curriculum from all three school district. Efforts were made to align the unit development with district curriculum and state standards.

Duration

As previously mentioned in the literature review portion of the paper, duration can be viewed through two lenses. The first being number of hours, the second being time span. This particular professional development intervention took place over the course of three months, for a total of 21 hours. The literature supports effective professional development as being anywhere from 15-80+ hours (Supovitz & Turner, 2000; Yoon et al., 2007). Due to the narrow focus of the professional development intervention, 21 hours seemed sufficient to cover the content and practices effectively.

Content Knowledge

The unit was comprised of three distinct areas of study within the physical science curriculum. The first portion began with an introduction of atoms, elements, and compounds. Scaffolding of content was also infused within the activities where necessary. The second area of study within the unit attended to states of matter and their properties. Finally, the third content area was comprised of physical and chemical changes, where a variety of experiments helped participants construct the knowledge their students would duplicate within the classroom. In addition to the above content areas, facilitation of discussions around inquiry, research, and authentic science practices were interwoven throughout the unit.

Active Participation

Teachers actively participated in activities that were later implemented in their classrooms. Taking on the role of a fifth grader enabled the teachers to construct their own knowledge of science concepts, and also allowed them to work through any other potential issues that may arise with their students. For example, during Week 1, teachers participated in a card sort activity where they were asked to sort some playing cards. This activity was extended to the periodic table where considerable time was spent discussing the organization of the periodic table. Teachers were given the opportunity to build atoms of different elements using toothpicks and candy. Once they built their atom, they shared with others and took turns guessing which atom their colleagues had made. To build on this concept, the next topic included investigating the vocabulary of molecule, compound, and element. Teachers were then given Legos to make representations of each. Discussions of inquiry and questioning strategies were interwoven into the activities. At the conclusion of the first evening, a discussion and video on the Next Generation Science Standards practices was shared and teachers were given the opportunity to identify practices within the video.

During the session involving properties of matter, one activity involved investigating the movement of food coloring through different temperatures of water and a block of ice. Teachers were able to see the movement of the food coloring molecules indicating the speed of molecules in different temperatures (see Appendix B). For the session on chemical changes, one activity involved placing a variety of elements in a Ziploc bag and observing various reactions (see Appendix B). This "Chemistry in a Bag" activity allowed participants to investigate which combination of elements produced heat, and which produced gas. The elaboration of this activity involved using Legos to simulate the reaction. This was an especially powerful experience for participants in that they could see an abstract concept of new material being produced with no leftover Lego. Discussions ensued and teachers decided that it would be interesting to let the students choose their own Lego combinations to recreate the reaction and then create a key of elements.

Collaboration

Teachers also had the opportunity to work collaboratively to integrate science lessons with relevant areas of the curriculum, such as mathematics and language arts. Lively discussions and debates helped to build content and confidence. In addition, a google site was created as a means to share documents, activities, and other relevant material. The sharing of materials and ideas through this site seemed to enhance the experience for the teachers by building a community.

Follow Up

Follow up for this professional development occurred during the last session. The teachers had met for six sessions previously, and were given a month off in order to take time to implement the unit within their classrooms. At the follow up session, teachers shared their experiences of implementation and discussed topics such as what went well, what didn't, and what could be done differently. This follow up session was also an opportunity to trouble shoot issues that were not anticipated. One such issue was the fact that the students had not used digital scales before, and were not familiar with the idea of taring a scale. This led to the conclusion that a mini lesson on scale use was necessary before implementing some of the activities.

Materials

To support this project, teachers in both groups were provided with a materials kit. The experimental group was also provided with other resources necessary to duplicate activities within their classrooms. In addition, teachers in the experimental group responded to periodic written reflections throughout the professional development process. Reflections were guided by prompts provided by the researcher.

Instrumentation and Operationalization of Measures

This study utilized several data collection instruments. The following section provides information on each of the measures used in this study.

LSC Observation Protocol

An observation protocol evaluated the quality of science lessons of elementary teachers both before and after the professional development intervention. The same measure was used for both the treatment group and the control group in order to determine if the professional development intervention had an impact on lesson quality. The specific tool used for this measure was the Local Systemic Change Protocol, or LSC Protocol (Banilower, 2005). This observation tool is made up of four scaled categories.

Categories include lesson design, implementation, content, and classroom culture (see Appendix C). The scales range from “not at all” to “to a great extent” when rating the presence of specific practices. For each category there is also a synthesized rating score on a scale of 1-5, with 1 indicating poor quality, and a 5 indicating high quality. Content validity was established for this protocol by 60 math and science educators. Reliability scores indicate 92% of raters selected quality levels within one level, while 57% of raters rated levels exactly the same. The sub-categories for each area showed strong internal consistency ratings. A Cronbach’s alpha level was above .9 in all categories (Banilower, 2005).

For this study internal consistency reliability was calculated for each of the four categories. Results of this analysis produced a Cronbach’s alpha of .781 for lesson design, .696 for implementation, .577 for content knowledge, and .205 for culture. The low alpha for culture results from differences of two points in just two scores. The limited size of the data set produced wide fluctuations in reliability with only a few scores. The low consistency reliability issue for culture will be discussed in more detail in the results section.

Project 2061 Assessments

Several measurement tools were used to measure the dependent variables in order to support the theoretical framework of the study. The first of these was a measure of content knowledge for teachers. The main focus of this content test was on common science misconceptions. This measure was developed using the Project 2061 Assessment. This assessment program allowed for custom made test development for specific science content topics. After choosing the topic of physical science, the researcher was able to go into the bank of questions available and select those relevant to the unit. Twenty test items were chosen. These test items were developed with funding from the National Science Foundation. The Project 2061 test items have undergone an extensive development process and have been nationally normed (AAAS, 2014). For this study, reliability for this test was acceptable with $\alpha = .70$ after deleting 4 of the 20 test items. Participants repeated this test again in late May after the professional development intervention for the experimental group, and again reliability was acceptable with $\alpha = .72$ after deleting 4 of the 20 test items.

Science Teachers' Efficacy Beliefs Instrument

Another measure was used to assess self-efficacy of teachers in the study. The Science Teachers' Efficacy Beliefs Instrument (STEBI) was used for this measure. In keeping with the theoretical framework, the final STEBI was administered both before the professional development intervention and after results from the student assessment have been shared with teachers (see Appendix D). This survey is a self-report survey designed specifically for elementary science teachers. The STEBI is a widely used measure in the science education arena. Using internal consistency of survey items, reliability coefficients of .92 are reported in the literature (Riggs & Enochs, 1990). The STEBI was initially tested using a pool of 71 elementary teachers enrolled in graduate school. Through this process, items on the STEBI were revised and refined. Construct validity was established by measurement experts. Any items that were scored inconsistently by 3 out of 5 judges were eliminated (Riggs & Enochs, 1990)

For this study, reliability was calculated for each subscale separately for both the pretest and posttest. Results of the reliability analysis for the pretest produced an alpha of

.89 for the PSTE subscale and .64 for the STOE subscale. For the posttest, the reliability analysis produced an alpha of .76 for PSTE, and .78 for the STOE.

Project 2061 Assessment for Students

Students of the teachers in the study were given the same content knowledge assessment as the teachers from Project 2061. Reliability for the pretest for students was slightly low ($\alpha = .56$), but this may be due to the fact that many of the students got most of the answers incorrect on the pretest. For the posttest, reliability increased ($\alpha = .64$).

Engagement Survey

The Modified Attitudes Toward Science Inventory (mATSI) was administered to students of teachers in both the control and experimental groups both before and after the professional development intervention. The mATSI is a modified version of the Attitudes Towards Science Inventory (Weinburgh, 1994). The modification process included shortening the survey from 48 to 25 items to accommodate younger students (Weinburgh & Steele, 2000). The mATSI was piloted with 1404 5^{th} grade urban students to establish reliability and confirm the readability of the vocabulary in the survey. This survey measures five different sub-categories including perception of science teacher, anxiety towards science, value of science in society, self-concept of science, and desire to do science. The overall corresponding Cronbach's Alpha for each subcategory in the pilot study was acceptable ($\alpha = .63, .71, .62, .68$, and $.78$). For this study, following the above order, the reliability for the pretest for each category was calculated separately for each category was also acceptable ($\alpha = .55, .81, .71, .81, .77$). For the posttest, reliability was solid ($\alpha = .75, .77, .82, .78$, and $.84$).

<u>Administration of Measures</u>

Both the content knowledge test and the self-efficacy for science teaching science survey were administered to teachers both before and after the intervention. The STEBI post-test was administered only after student results from the student content test and attitude survey were shared with teachers. A composite score sheet was sent to teachers showing student results from both the pre and posttests of the content test and the student attitude survey (see Appendix D). In addition, a word document explaining the scoring was included. Using Guskey's framework as a model, Guskey argues that sharing student outcomes with teachers prior to measuring changes in self-efficacy is an important step in the change process for teachers (Guskey, 2002).

Both the content knowledge test and the self-efficacy survey were administered on line. In addition, the LSC observation protocol was used to evaluate video recordings of teacher science lessons for quality. Teachers from both the control and treatment groups were asked to present their best science lesson for the video both before and after the professional development intervention.

Independent raters evaluated the videos using the observation protocol. Two of the four raters are clinical faculty in a university STEM teacher preparation program. Their current job description includes providing feedback to pre-service teachers on inquiry based math and science lessons. Their education and expertise aligns well with the needs of this study. The other two raters are current veteran elementary teachers who have extensive experience within science leadership roles in their districts. Both teachers have over 20 years of teaching experience. Two pairs of raters were assigned four of the same videos to rate to establish inter rater reliability. Percentages of same ratings as well as percentages of ratings within one level were used to establish inter-rater reliability.

The student data collected included a content knowledge test both before and after the unit instruction, which was the same content test administered to teachers.

Students were also asked to complete a science attitude survey both before and after the professional development project. These measures were administered to students of teachers of both the control and treatment groups before and after the professional development intervention.

Data Analysis Plan

Due to the quasi-experimental design of this study, an ANOVA was conducted for several of the measures to determine if there is a significant difference between the control and treatment group. A 2 x 2 repeated measures design was used for the content test for both teachers and students, both subtests of the self-efficacy survey, and the six components of the science attitude inventory. For the video observations, a one way ANOVA was performed using the groups and the change in overall scores for the observation protocol.

In addition to tests of significance, reliability analyses were conducted on each of the measures, both for pretests and posttests. Cronbach's alpha is reported for each measure to establish reliability.

Finally, in order to reveal relationships between components of Guskey's model, several Pearson correlation analyses were performed. First, a correlation between the gain scores of the observation protocol and student gains on the content test were correlated. This correlation was performed in order to connect lesson quality with student outcomes. In addition, another correlation was performed to unveil the relationship between self-efficacy and student content tests. This correlation was conducted for the PTSE and STOE portion of the STEBI separately. Finally, a correlation between lesson quality and teacher self-efficacy was conducted. Gain scores on each were used to calculate these correlations.

Qualitative Analysis

For the qualitative portion of this study, specific reflection prompts were given to teachers in the experimental group at three different times throughout the professional development project; once at the beginning, once in the middle, and one at the end (see Figure 11). The prompts were designed to help determine relationships between the four components of professional development, teacher practice, student outcomes, and self-efficacy. This data also helped to triangulate findings from the quantitative measures.

Week 1	1. How would you describe your knowledge and understanding of physical science content? What effect does your knowledge and understanding have on your science teaching? 2. Describe your confidence for teaching science? What affects your confidence in teaching science? 3. With your current teaching practices for teaching science, what do you notice about your students?
Week 4	4. What have you learned in the professional development thus far? Has it changed the way you teach physical science or think about teaching physical science? 5. Have you noticed any changes in your students as a result of changes in the way you teach science? How do these changes influence your confidence for teaching physical science? 6. Describe your confidence for teaching science? What affects your confidence to teach science?
Week 8	7. To what extent has the professional development experience impacted your practice? 8. Describe how the professional development has changed your confidence about teaching science? 9. How have the new practices you have implemented impacted your students? How do your students influence your practice?

Figure 11. Prompts Provided to Teachers for Reflective Journals

In order to systematically analyze the qualitative data, a specific structured coding procedure was utilized. Once all responses to the reflection prompts were obtained, responses were copied and pasted into an excel document. This allowed for the researcher to analyze the data line by line. Through this objective examination process, codes and themes that emerge were recorded in a column to the right of each line of the document. This process was repeated several times in order to identify all codes and themes.

Once the codes and themes were recorded in this manor, the data was organized by each of the three main questions that were asked throughout the professional development. The first question repeated throughout the reflection involved teacher practice. These question responses along with the corresponding codes were placed on a timeline indicating themes and codes at the beginning, middle, and end of the professional development. Likewise, this process was used to evaluate the responses to the second main question asked in the prompts throughout the professional development process. These prompts focused on confidence to teach science. Finally, responses to questions regarding student engagement and their corresponding themes were also organized on a timeline to indicate change over time.

The following graphic was created to illustrate how the qualitative prompts fit into the quantitative measures of the study.

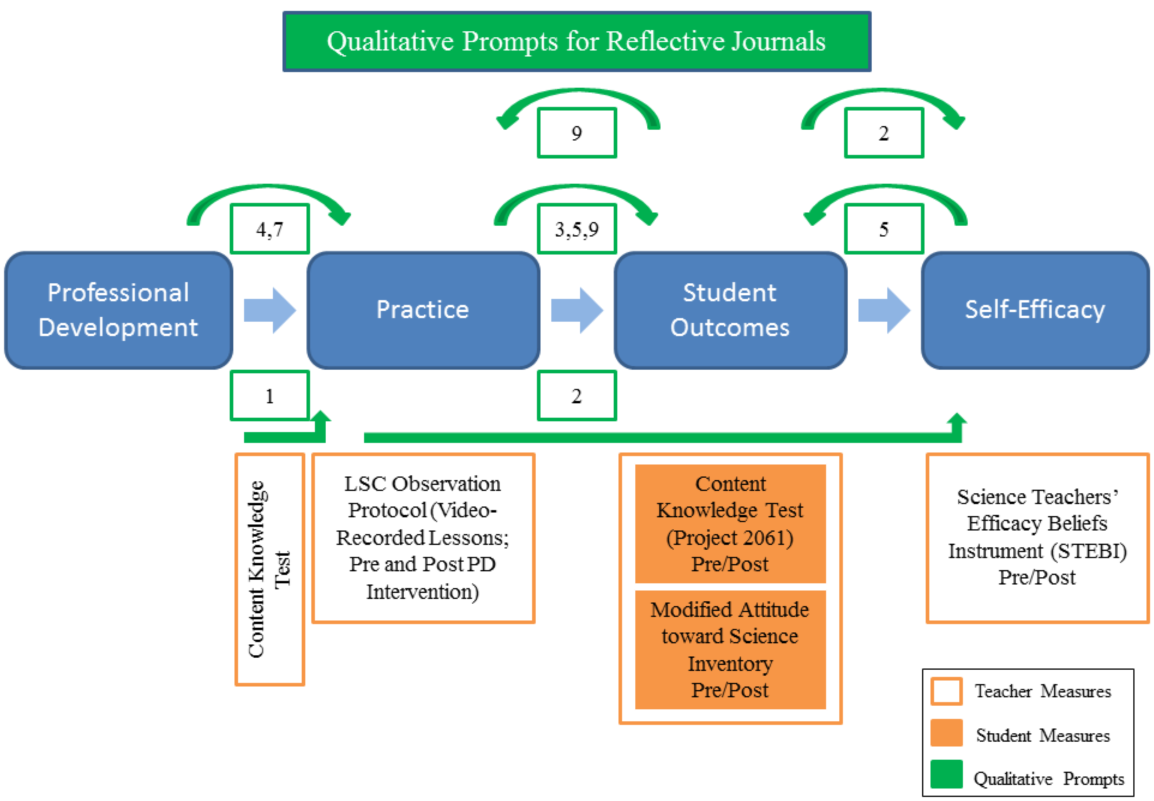

Figure 12. Research Design Graphic

Threats to Validity

Internal Validity

Due to the complex nature of this study, internal validity issues do exist. The complicated relationship between, practice, content knowledge, and student outcomes and self-efficacy make it difficult to pinpoint which of these features, or which combination of features are changed due to professional development. Also, relationships between these components are not cut and dry. To alleviate some of the threats to internal validity, the measures chosen in this study are highly reliable and valid. These measures were also chosen because they are believed to be effective in measuring the constructs described in Chapter 1.

Another concern in terms of internal validity is experimenter bias. The researcher was the professional development provider. To mitigate this threat, outside raters were hired to evaluate the videos using the observation protocol.

External Validity

In addition, there are some threats to the external validity of this study. Recruiting elementary teachers to participate in science professional development was a challenge. Even with incentives of credits and science kits, only 11 teachers from three fairly large school districts volunteered to participate. Generalizing to the population with only 11 teachers is a challenge. In addition, the teachers who participated self-selected for this study which suggests they may gave a higher interest in improving science instruction than the average teacher.

Ethical Procedures

Approval from Boise State's Institute Review Board was obtained for this study (see Appendix E). Confidentiality practices were given a high priority. Pseudonyms were given to each participant to protect their identity. Likewise, students of each teacher used student ID numbers instead of names, of which the researcher had no connections to student names. Videos of classroom lessons were kept on a password protected computer, and all documents associated with this study were kept in a locked file cabinet in the researcher's office at Boise State University.

Summary

In order to make impactful contributions to the teacher education community, the design of this study was carefully constructed in order to provide the most opportunities for new knowledge in the field. By combining elements of effective professional development and components of professional development, the potential to unravel the complexities of these intricate relationships is possible. By including the qualitative piece of reflective journals, an opportunity to uncover rich data associated with the components of professional development enhances the study.

CHAPTER FOUR: RESULTS AND ANALYSIS

Introduction

The following sections detail the results from several different measures used in this study. Consistent with the organization of the literature review, this section will also follow the order of Guskey's model for professional development. In addition to the quantitative measures, qualitative pieces from teacher reflections will be interwoven throughout this chapter where appropriate. Throughout this chapter Group 1 refers to the treatment group of teachers and their students, while Group 2 refers to the control group of teachers and their students.

Professional Development

Content Knowledge of Teachers

Within the first component of Guskey's model, professional development, the element of content knowledge was measured using the Project 2061 content misconceptions test for physical science. This test was developed by the American Association for the Advancement of Science, and test items were selected by the researcher from a bank of questions (see Appendix F). The focus on teachers' content knowledge was an important element included in the professional development experience for the treatment group of teachers. This first measure answers the second research question of the study:

- *Does participation in a comprehensive professional development intervention focused on an integrated science unit increase science content knowledge of elementary teachers?*

Teachers in both the treatment and control groups took a pretest of physical science misconceptions in late February prior to the professional development intervention for the treatment group. The posttest was administered in May following the professional development intervention.

Using a mixed factorial ANOVA, with $F(1,8)$ =.157, and MSe = 132.22, p = .702, *partial eta squared* = .019, results indicate that there was no significant difference between the control and treatment groups. Due to the limited number of participants, and the fact that the participants self-selected for this study these results are not surprising. In addition, data from one teacher in the control group could not be used due to the fact that her pretest was incomplete.

Table 3
Teacher Scores on Science Content Misconceptions Test

	N	Pretest (SD)	Posttest (SD)
Treatment	6	85.83 (9.7)	88.33 (8.16)
Control	4	81.25 (12.5)	88.75 (6.29)

Teachers' pretest scores in both groups were already high, with an average score of 85% for the experimental group and 82% for the control group. Finding significant growth from this high starting point was fairly unlikely. Another issue to consider is the alignment of this particular measure with the professional development unit. Perhaps if the measure was more closely aligned to the content covered in the professional development, differences between pre and post tests may have been more substantial.

Teacher Practice

The next component of Guskey's model is teacher practice. Video observations were used to collect data on the quality of the teachers' lessons both before and after the professional development intervention for the experimental teachers. The LSC Observation Protocol was used to rate each lesson (see Appendix C). This section of the results answers the first question of the study:

- *Does participation in comprehensive professional development focused on an integrated science unit improve the quality of elementary science lessons?*

Two pairs of raters were assigned different videos, with an overlap of 4 videos per pair in order to establish reliability. Each teacher was rated on four areas: design, implementation, content knowledge, and culture. Each pair of raters was responsible for rating 11 videos, with four of the 11 videos rated by both raters. With the four categories for each, 32 scores were produced by two raters. Of these, 31% of the ratings were the same, while 57% differed by one point on the five point scale. Nine percent differed by 2 points, while 3% differed by 3. Compared to the Horizon Research initial tests for inter-rater reliability, where 92% of ratings were within 1 point, 88% of ratings in this study were within one point on the five-point scale (Banilower, 2005).

If teacher videos were rated by two raters and scores differed, an average between the two scores was calculated. Each teacher's scores from before and after the professional development intervention are shown in Table 4.

Table 4
LSC Protocol Scores

		Pre-Videos				*Post-Video*				*Change*				**Overall**	**Overall**
Teacher	**Group**	**D**	**I**	**Ct.**	**Cu.**	**D**	**I**	**Ct.**	**Cu.**	**D**	**I**	**Ct.**	**Cu**	**Change**	**No Cu.**
Amy	1	3	4	3.5	4.5	5	4	5	4	2	0	1.5	-0.5	3	3.5
Mark	1	2	2	2	3	3	3	1	3	1	1	-1	0	1	1
Melissa	1	5	4.5	4.5	5	5	5	5	4	0	0.5	0.5	-1	0	1
Beth	1	3.5	3.5	3	3	3.5	3.5	3.5	4.5	0	0	0.5	1	1.5	0.5
Tom	1	4	4	5	5	5	5	5	4	1	1	0	-1	1	2
Sarah	1	3	2.5	2.5	3	4	4	4	3	1	1.5	1.5	0	4	4
Michelle	2	3	3	3	3	3.5	2.5	2.5	3	0.5	-0.5	-0.5	0	-0.5	-0.5
Susan	2	3	4	4	3	3.5	3.5	3.5	3.5	0.5	-0.5	-0.5	0.5	0	-0.5
Tammy	2	4	4	3.5	4	2	2	3	3	-2	-2	-0.5	-1	-5.5	-4.5
Claire	2	3	2.5	3	2.5	2	3	3	2	-1	0.5	0	-0.5	-1	-0.5
Nancy	2	2.5	2.5	2.5	3.5	2	2	2	2	-0.5	-0.5	-0.5	-1.5	-3	-1.5

(D=Design, I=Implementation, Ct.=Content, Cu.=Culture; Group 1= treatment group)

In examining the above data, the expected change for the control group is minimal due to the fact that no interventions were given to this group. For the most part, this appears to be true, with the exception of Tammy. Tammy had some large variability in her scores from pre to post, which was unexpected. It’s unlikely that Tammy has decreased the quality of her lessons overall in a two month period of time. The other teachers in the control group had minimal overall change, especially in the last column where the change for culture was removed due to the poor reliability of this component. Also to consider, is that scores including .5 are the result of averaging the scores of two raters. For example, if one rater gave a score of 3, and the other a score of 4, the average score given to that teacher was a 3.5. When looking closely at the control group data, there are many instances where a teacher showed a slight change with one rater, but not the other, thus resulting in an average change score of .5. Removing Tammy, 10 out of the 12 remaining change scores for the other control group teachers show this .5 change.

This observation supports the notion that the quality of the lessons of the control group stayed relatively constant.

A one way ANOVA was performed to compare the overall changes in teacher practice of the two groups. In order to answer question two of the study, it was important to look at the change in practice. Analysis was conducted twice; once including Tammy and once without. Including Tammy, results produced an $F(1, 9) = 13.36$, $MSe = 33.4$, $p = .005$, results indicate that teachers in the treatment group experienced significantly larger overall gains on the observation protocol than the teachers in the control group (see Table 5). Removing Tammy produced similar results with an $F(1, 8) = 12.907$, $MSe = 19.150$, $p = .007$. These results support the idea that focused professional development that incorporates proven elements of successful professional development can improve teacher practice.

Of course, given the high variability of Tammy's scores, it is important to consider that this type of variability could exist with any of the teachers; including the teachers in the treatment group. Again, a larger sample size would be necessary to gain a better understanding of the impacts professional development can have on teacher practice.

Table 5
Comparisons of Overall Change on Observation Protocol Scores (without Tammy)

	N	Mean	SD
Treatment	6	2	1.45
Control	4	-.75	.5

In addition to the videos, reflection prompts addressing practice for teaching science were given to teachers in the treatment group at three different times throughout the professional development intervention (see Appendix G). Responses further triangulate the results of the observation protocol. As noted in Table 6, teachers appeared to experience a change in practice as a result of their experiences in the professional development workshops. Unfortunately, Sarah did not respond to the prompts, so her responses are not included.

Table 6
Teacher Responses to reflection prompts regarding practice

	First Reflection	Midway Reflection	Final Reflection
Participant	**How would you describe your knowledge and understanding of physical science content? What effect does your knowledge and understanding have on your science teaching?**	**What have you learned in the professional development thus far? Has it changed the way you teach physical science or think about teaching science?**	**To what extent has this professional development experience impacted your practice?**
Amy	*I have a pretty basic understanding of many physical science concepts, but cannot explain them all in depth. I am not afraid to explore and learn along with my students, but I am not as comfortable teaching concepts for the first time.*	*I have learned that the inquiry approach allows for much more discussion and questioning by students. I am enjoying teaching more, although the management and cost of materials can sometimes be tricky.*	*I am using more inquiry based lessons and more focused on the 5 E format.*
Mark	*Average~ my understandings about science is that you need opportunities to try, discuss, and try again. Materials are needed and time that will allow learners to explore.*	*I have collected some great new activities and fantastic ways to teach physical science. It has forced me out of the textbook and into developing understanding of the concepts such the periodic table, atoms, molecules, chemical and physical changes etc.*	*I have learned more and understand better about the curriculum that I teach. Receiving training to teach labs or experiments with the students has provided me more confidence without the many hours of needed research.*
Beth	*I would describe my understanding of physical science as being elementary. I can research to find necessary information as needed to reach learning targets and enduring understandings but it does not come naturally.*	*The labs that we have had the opportunity to practice lessons have been fun, engaging, and rich in content.*	*This has been a great catalysis for teaching science and developing understanding with kiddos. The activities are fun and engaging for me as the teacher and for the kids.*
Melissa	*I think my knowledge is basic. Physical science is not my*	*I have learned some great labs, with strategies for*	*It has given me many exciting labs to tie with*

	favorite and I always feel that I am reaching for ways to make it exciting.	*discussion and inquiry. I have also built my knowledge base, which has improved my confidence in teaching physical science.*	*content reading.*
Tom	*I feel I am fairly proficient with my understanding of physical science content. I feel this has a great effect on my teaching because I do not always have to refer back to the book to give students answers.*	*For me, I have been learning as I go since I am unable to attend the meetings. Personally I like this method because I can go at my own pace. It has not changed the way I teach science or think about science yet.*	*It has given me more tools in my toolbox. New lessons, materials, etc.*

Amy notes, *"I am using more inquiry based lessons"*, while Tom states, *"It has forced me out of the textbook."* Several post-hoc themes emerged through an evaluation of the reflections regarding practice. These themes are represented on the following time line indicating change over time.

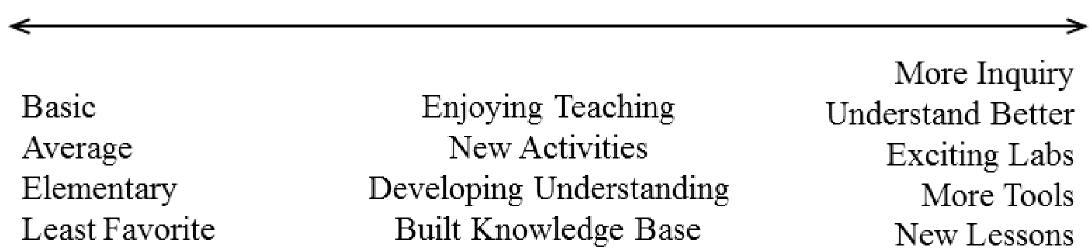

Figure 13. Themes from reflections on practice over time

As discussed and empirically supported in the literature review section of this paper, changes in science teaching practice such as inquiry result in increased understanding and engagement for students. Increasing teacher confidence is another benefit that will hopefully encourage the teachers to continue these new practices for science instruction.

Student Outcomes

Content Knowledge of Students

The third component, and perhaps the most important component, of Guskey's model for professional development is student outcomes. Two different measures were administered to students of teachers in both the experimental and control groups. First, the same content misconceptions test that was administered to teachers was also administered to students. This test answered the third question of the study:

- *Do the students of the teachers who participated in the professional development project show increased test scores over students of teachers who did not participate in professional development?*

Using an ANOVA mixed factorial analysis, with an $F(1,182) = 7.174$, $MSe = 2357.76$, $p = .008$, *partial eta squared* =.038, results indicate that students of the teachers in the treatment group significantly increased their scores over the students of teachers who did not participate in the professional development intervention (see Table 7).

Table 7
Student Scores on Science Content Misconceptions Test

	N	Pretest (SD)	Posttest (SD)
Treatment	91	32.25 (12.96)	43.41 (14.6)
Control	93	39.46 (14.5)	46.33 (18.19)

In addition, since the estimated interaction between the test and the group approached significance with a $p = .076$, tests of simple effects were performed to gain a more specific analysis of the relationships between the different factors. The results of these tests indicate that there was a significant difference between the pretests of each group. With $F(1,182) = 7.274$, $MSe = 328.65$, $p = .01$, results are significant. The other comparisons of factors did not show significant differences.

As indicated in Figure 14, the teachers' students in the treatment group were lower than the teachers' students in the control group at the start of the study with regards to scores on the content misconceptions test. A variety of factors account for this difference related to assignment of teachers to the treatment and control groups.

Initially, when assignments of teachers were randomly made, a decision was made to ensure teachers from same schools would belong to the same group. Three teachers of the eleven in this study were all teaching at a high SES school with a focus on STEM. When one of the teachers from this school was randomly assigned to the control group, the other two were automatically placed in the control group to avoid contamination of the study groups. Although these differences were significant at the start of the study, it appears that the students of teachers participating in the professional development were able to catch up to, or even surpass, the students of teachers in the control group.

Consideration should be given to the fact that gains made on the physical science misconceptions test were minimal, even for the treatment group. Each question on the 20 point test was worth 5 points. Student gains on the test for all groups ranged from -1.88 to 18, which is about a negative half a question to 4 ½ questions. The difficulty of the questions was definitely an issue. These questions were originally designed for 6th-12th graders, and although questions related to the unit were chosen for the test, the difficulty factor seemed to impact the scores. Like the teachers, perhaps if the measure was more closely aligned to the content covered in the professional development, differences between pre and post tests may have been more substantial.

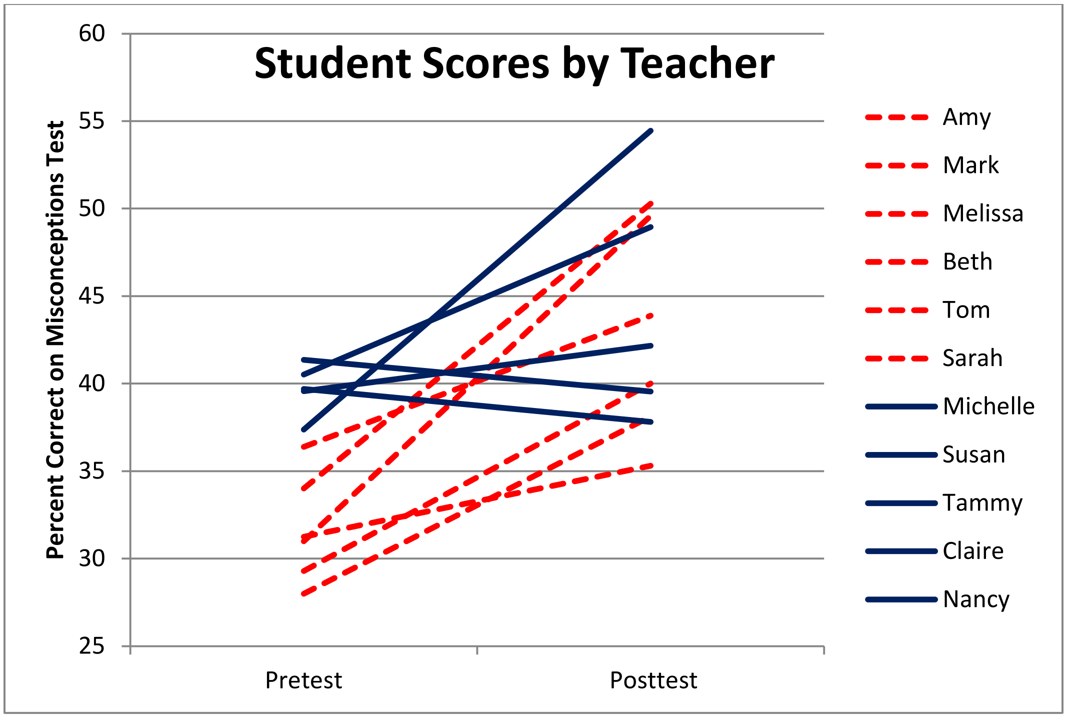

Figure 14. Student scores on Content Misconception Test (dashed=treatment group)

One interesting aspect to this study was the fact that Tom was unable to participate in the workshops due to other obligations. Instead of losing Tom as a participant, plans were made to video record each session, and provide these video recordings for Tom to watch at home. Interestingly, Tom's student score gains for content misconceptions were considerably lower than the rest of the treatment group (see Table 8). Tom did miss out on actively participating and trying out experiments with the group. This missing element may have negatively impacted his content growth, which in turn may have impacted his students.

Table 8
Student Average Content Misconception Gains by Teacher

Teacher	Student Gains
Amy	18.59
Mark	7.5
Melissa	16.29
Beth	10.71
Tom	4.06
Sarah	10.125

Student Engagement

Another measure of student outcome for this study was the Modified Attitudes Toward Science Inventory. This survey was administered both before and after the professional development intervention to all students in the study. This survey measures five different sub-categories including perception of science teacher, anxiety towards science, value of science in society, self-concept of science, and desire to do science.

The results of this survey help answer the 4th question of this study:

- *Do the students of the teachers who participated in the professional development project show increased engagement over students of teachers who did not participate in professional development?*

A mixed factorial ANOVA was performed on each of the sub-categories for the Modified Attitudes Toward Science Inventory (MATSI). None of these results indicated significance, with F values ranging between .019 and 1.377, and p values ranging from .242 to .892.

Although no significance was found between the students of the treatment group teachers and the students of the control group teachers in any category of the MATSI, some note-worthy comments were made by participating teachers that support the notion that when teachers see engagement and excitement in their students when using specific science practices, they are motivated to continue the practice, which in turn may impact their self-efficacy as well as their beliefs in the effectiveness of the practice (see Table 9).

Table 9
Teacher Responses to Reflections on Student Engagement

	First Reflection	Midway Reflection	Final Reflection
Participant	**With your current teaching practices for teaching science, what do you notice about your students?**	**Have you noticed any changes in your students as a result of changes in the way you teach science? How do these changes influence your confidence for teaching physical science?**	**How have the new practices you have implemented impacted your students? How do your students influence your practice?**
Amy	*I notice that my students are often engaged and interested when we have hands-on activities or classroom discussions. I have less understanding and participation when we are reading out of the textbook.*	*My students are much more inquisitive and usually extend experiments or come up with new questions. They also seem to be making connections more quickly to related content, than when we just read text or watch videos.*	*My students are much more excited about science and enjoying the learning more. I respond better to engaged, excited students, so that reinforces my willingness to continue this approach.*
Mark	*They want to explore or experiment more with science concepts.*	*This has made science more of a priority and exciting for me.* ****It's easier to avoid or "gloss" over things when you are bored teaching it and the kids pick up on the attitude so they are also bored.*	*Inquiry based lessons provide my students and I flexibility to learn and teach as needed. Naturally discovering ideas and understandings about the taught content.*
Beth	*I notice that my students are super excited about learning science but I wish I could dedicate more time to it in an effort to keep them interested.*	*Yes, I don't have to research for the lessons and the materials are already organized and supplied to us.*	*The student's enthusiasm has a tremendous influence on my practice of science. I am excited to initiate more experiments and find the materials necessary for each lesson.*
Melissa	*They love the hands on... Struggle with content area reading.*	*My students are far more engaged with hands on learning.*	*Students have been extremely excited over the labs and easily explain concepts that were abstract before, such as sublimation. Student engagement is always a driving factor for how I plan lessons.*
Tom	*Because my students haven't been as exposed to Science as I'd like, I feel that the students really enjoy Science. They like the investigation piece to it. They enjoy learning new*	*My students love science because it's something different than the usual ELA or Math that we have to do. This doesn't influence my confidence, it just makes me want to teach it more and*	*It's showed the students that science can be fun. And because I have seen this joy in their eyes, it makes me want to do more and more science.*

	things.	*more.*	

Several common themes emerged in the teacher reflections regarding student engagement. These themes are represented on the following time line indicating change over time.

		Much more excited
Hands-on activities	Making connections	Naturally discovering
Experiments	More inquisitive	Enthusiasm
Struggle with content	Science a priority	Extremely excited
Check out if using book	Far more engaged	Driving Factor

Figure 15. Themes in teacher reflection regarding student engagement over time

Several teachers referred to the less engaging textbook approach to learning science. Mark references his own boredom, “It's easier to avoid or "gloss" over things when you are bored teaching it and the kids pick up on the attitude so they are also bored.” Amy notes that her own understanding wanes with the use of the textbook. “I have less understanding and participation when we are reading out of the textbook.” As time progressed through the professional development experience, the reflections expressed a pattern of increased enthusiasm for science for both teachers and students. Teachers’ motivation to teach science seemed to have a strong connection to the engagement of their students. Tom illustrated this point when he wrote, “I have seen this joy in their eyes; it makes me want to do more and more science.”

Self-Efficacy and Beliefs

The final component of Guskey's theoretical framework for professional development is self-efficacy. The instrument used to measure this component was the Science Teacher Efficacy Beliefs Instrument (STEBI); an instrument specifically designed for elementary teachers (see Appendix H). Teachers in both groups took the STEBI before and after the professional development intervention. The post STEBI was administered only after student scores were shared with the teachers. This was an intentional aspect of the design of the study as described in the methods section of this paper.

The STEBI consists of two subscales; Personal Science Teaching Efficacy (PSTE), and the Science Teaching Outcome Expectancy (STOE). Results of this analysis help answer the third research question of this study:

- *Does participation in a comprehensive professional development intervention focused on an integrated science unit improve the self-efficacy of elementary teachers?*

Results were calculated using a mixed factorial ANOVA. With $F(1,11)=10.651$, *MSe* = 161.024, $p = .010$, *partial eta squared* = .542, significant differences were found between the pretest and posttest on the PTSE subscale for both the control and treatment group. Teachers who participated in the professional development opportunity did increase their self-efficacy. With a *p*-value of .478, differences between the groups for the PTSE were not significant. Likewise, no significant differences were noted on the STOE portion of the Science Teaching Efficacy Beliefs Instrument ($p = .445$).

On further analysis, two teachers in the control group experienced very high gains on the PSTE portion of the self-efficacy survey (see Table 10) The reasons for these large gains are unknown, but this growth did skew the data from the control group, which in turn contributed to the lack of significance between groups.

It's important to acknowledge that both groups experienced significant changes in the PTSE portion of the STEBI. This suggests that the professional development may not be the reason for the increase. Perhaps as teachers delve into a new unit, they gain confidence as they work through the unit with their students. Again, having a larger sample size would help to more clearly prove that the professional development was the reason for an increase in self-efficacy.

Table 10
Teacher gains in the PSTE portion of the STEBI

Group	Teacher	PTSE Gain
1	Sarah	15
1	Mark	2
1	Beth	6
1	Melissa	6
1	Amy	4
1	Tom	7
2	Michelle	12
2	Nancy	-2
2	Susan	-2
2	Tammy	10
2	Claire	3

Teacher responses to reflection prompts are detailed below. These responses may help to shed some light of the impact the professional development had on their self-efficacy (see Table 11).

Table 11

Treatment Group Responses to Reflection Prompts Regarding Confidence

	First Reflection	Midway Reflection	Final Reflection
Participant	**Describe your confidence for teaching physical science.**	**Describe your confidence in teaching science. What affects your confidence to teach science?**	**Describe how the professional development has changed your confidence about teaching physical science.**
Amy	*My confidence in teaching science is affected by the interest level of my students and how engaged I can make the learning, as well as by the depth of my understanding.*	*I have always enjoyed teaching science, but I am much more comfortable with what I don't know, putting myself in the same place as students.*	*I have about the same level of confidence, as I've always enjoyed doing hands-on activities.*
Mark	*Time, material, and assessments impact my teaching science effectively.*	*My confidence has definitely grown in the past month. Science is my weakest area and something I have struggled with over the years although made my best effort.*	*It has provided me with lesson plans, opportunities to practice the experiments, and the materials. All relating to strengthening confidence in delivering the content*
Beth	*Science is my least confident category. The affect it has in my teaching is I feel it is the subject I dedicate the least amount of time to and the area where I rely mostly on the textbooks I have available.*	*My confidence comes from the actual practice before presenting the information to the class. Plus there is collaboration with my peers during the labs.*	*This professional development has changed my confidence completely. In the past I relied on the text and the activities supplied by the materials purchased from the district.*
Melissa	*I am fairly confident teaching science. There are topics I enjoy more than others. When I get to those less enjoyable topics, my confidence that I'm delivering sound, engaging instruction wavers.*	*I have always been fairly confident in teaching science concepts, with the exception of physical science. This has been due to minimal understanding of the concepts. This experience has improved that.*	*I have a better understanding of physical science and what the labs are teaching, this helps me explain it to students.*
Tom	*I love Science, I am extremely confident about teaching it as well. The only thing that hinders it is time.*	*I love teaching science, honestly I love to teach Reading through Science. I think me learning more and more about it really helps my confidence to teach it better.*	*I must admit, I do feel a little more confident with teaching science. At first I was reluctant, but after watching the videos and doing a few of the lessons I feel a lot better about it.*

Several common themes emerged in the reflection responses regarding confidence for teaching science. These themes are represented on a time line in Figure 16 indicating change over time.

		Opportunities to practice
Science least confident	Confidence has grown	Strengthening confidence
Rely on textbook	Confidence from practice	Changed confidence
Don't have solid grasp	Improved understanding	Better understanding

Figure 16. Themes in reflection regarding efficacy for teaching science over time

One notable theme that reappeared throughout the responses was the element of active participation. As noted in the literature review, active participation is an empirically supported element of successful professional development experiences for teachers (Desimone, 2009). Amy reflects how "*putting myself in the same place as the students*" increased her confidence. Similarly, Mark noted, "*it provided me with…opportunities to practice experiments*." Beth also shared the same thoughts, "*my confidence comes from the actual practice before presenting information to the class*." It is apparent through these reflections that the treatment group teachers experienced a change over time with regards to confidence. Active participation seemed to play a key role in this transformation.

Relationships between Components

Now that each component has been examined independently, it's important to examine relationships between the different components. Several analyses were performed to identify any potential correlations between content knowledge, practice, student outcomes and self-efficacy. This section highlights the findings of these analyses.

Lesson Quality and Student Achievement

The relationship between lesson quality and student achievement was analyzed using a Pearson's correlation. A moderate correlation was found between student content misconception gain scores and gain scores on lesson quality with r = .519 and p =.051. This moderate significance suggests that increased quality of lessons may coincide with an increase in student outcomes.

Teacher Self-Efficacy and Lesson Quality

Additionally, teachers' change in self-efficacy was correlated to the overall change in lesson quality. Using the overall change scores from the LSC protocol and the overall changes to the two subtests of the STEBI, Pearson's correlation coefficients were calculated.   No significance was found for the PTSE portion of the STEBI, however, for the STOE portion of the STEBI, with r = .771 and p < .05, a strong correlation between change in lesson quality and change in Science Teaching Outcome Expectancy was indicated.

Teachers' Self-Efficacy and Student Content

Next, the relationship between teachers' gains in self-efficacy and student growth on the content misconceptions test was analyzed. No significant correlation was found between Personal Science Teaching Efficacy (PTSE) and student content gains. However, with r = .597 and p = .052, a moderate correlation was found between the Science Teaching Outcome Expectancy portion of the Science Teaching Self Efficacy Beliefs Instrument and student content gains. This correlation is approaching significance (see Table 12).

Table 12
Correlations between the STEBI Gains and Student Content Gains

	N	R	P
PTSE	11	0.213	0.53
STOE	11	0.597	0.052

$p < .05$

Interestingly, the majority of the literature reviewed for this project using the STEBI typically report significant changes in PTSE, but no significant changes to STOE. The literature suggests that changing STOE is a much more complicated process due to the deeply ingrained values and experiences that drive how teachers think about students and their abilities. Teachers in this study increased their STOE scores, in some cases by a large percentage. Although these gains did not show significance, they are still an interesting phenomenon that should not be overlooked (see Figure 17). The limitation of the small sample size most likely played a role in the analysis results.

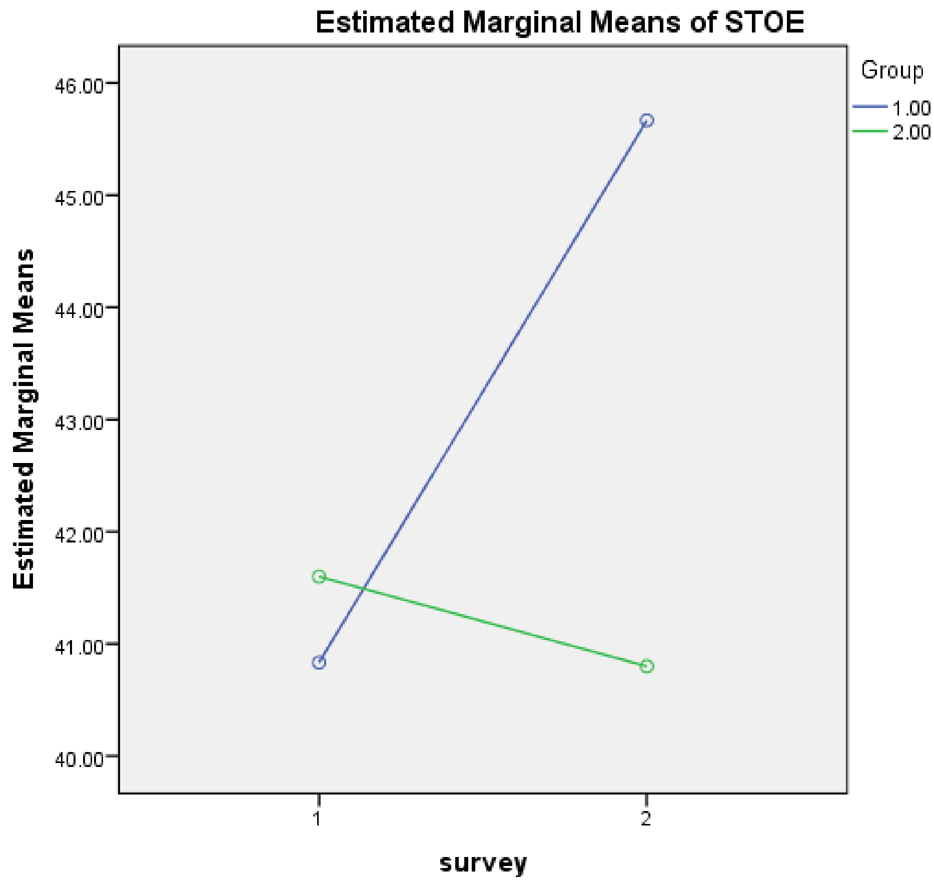

Figure 17. Comparison of changes in Science Teaching Outcome Expectancy portion of the STEBI (Group 1= treatment; Group 2= control)

Summary

Although this study was limited to 11 teachers, results indicate that impacts to practice, self-efficacy, and student outcomes can be achieved through comprehensive professional development experiences. Results from this study also help draw connections between the different components involved in the professional development process. By including qualitative data in this study, a deeper understanding about the professional development process was possible.

In the following chapter, a more detailed summary of the findings along with conclusions and implications for future research will be provided.

CHAPTER 5: CONCLUSION

Introduction

This research project sought to examine the impact of a carefully planned science professional development project on fifth grade teachers and their students. This project also investigated the complex relationship between the four different components of Guskey's theoretical framework for professional development: Professional development, teacher practice, student outcomes, and teacher self-efficacy. The findings of this study indicate that the relationship between components is perhaps even more complicated than originally perceived. This chapter will discuss findings, draw conclusions, discuss limitations to the study, and finally discuss implications for future research.

Summary of Findings

The construct of teacher learning is a complicated phenomenon. Researchers have engaged in a plethora of studies over the last several decades to empirically identify effective elements of professional development such as content focus, active participation, cohesion, collaboration, duration, and follow-up. The actual steps or components of professional development are more complicated. Several models exist, such as Guskey's model, yet empirical evidence supporting these models is virtually non-existent. This study sought to investigate these specific components as well as explore the relationships between these components. Using Guskey's model as a framework to guide this study provided a blueprint. The following summary of findings follows the order of Guskey's framework.

Beginning with the professional development itself, measures of teacher content knowledge were conducted both before and after the professional development intervention. No significance was found between the control and treatment group in terms of content knowledge gains. This is likely due to the limited size of the study and the fact that teachers self-selected for the study. Teachers in this study already had fairly high content knowledge for physical science. Another consideration is the possibility that the instrument used to measure the content growth was not aligned well to the professional development intervention. Further studies are needed that include a larger numbers of participants that are not self-selected. This type of intervention could produce more significant results.

The next component of Guskey's model, teacher practice, was measured using recorded science lessons and an observation protocol. Results from this component provide some evidence to indicate that teachers involved in the professional development intervention improved the quality of their science lessons compared to the control group of teachers. Teachers in the treatment group chose to implement new practices learned in the professional development workshops, while teachers in the control group appeared to implement similar practices that they had used at the beginning of the study. Although significant results were found between groups in terms of lesson quality, one teacher in the control group showed high variability in her lesson quality scores. This fact leaves unanswered questions regarding the reliability of this particular measure, and also opens up the possibility that treatment group teachers produced gains due to variability and not as a result of the professional development intervention.

The third component of Guskey's model, student outcomes, was investigated using two different measures. The first measure was the physical science content misconceptions test. Students of teachers in the treatment group experienced significant gains in scores compared to the students of teachers in the control group. Most notable in this comparison was the difference in pretest scores. Students in the treatment group scored significantly lower than control group students on the pretest due to a variety of factors. These students were able to make large enough gains to catch up or even surpass the control group students, thus supporting the effectiveness of the professional development intervention. With regards to these results, it's important to consider that lower students typically make larger gains than higher students, and that this may have been a factor in the results of this measure.

The second student outcome measure was the Modified Attitudes Towards Science Inventory. This survey was designed to measure five different aspects of attitude toward science: Perception of science teacher, value of science in society, self-concept in science, anxiety towards science, and desire to learn science. No significant changes were reported in any category. Again, the self-selection of participants may have been a limiting factor with this survey. Teachers in this study enjoy science, and most likely pass on this enjoyment and passion for science to their students. Students of teachers in both groups had fairly high scores in all areas of the student attitude survey, except anxiety, where a low score indicates low anxiety.

The final component of Guskey's model is self-efficacy. Self-efficacy surveys were administered before the professional development experience and again after the professional development. Before the post-survey, student scores from both student surveys were shared with teachers (see Appendix D). Guskey's idea of placing student outcomes before a change in self-efficacy derives from the idea that if teachers see positive student outcomes, this will in turn impact their self-efficacy. In this particular study, however, it appeared that the anecdotal observational evidence from students was more powerful than the numerical data provided to teachers. Within teacher reflections teachers' comments support this notion. As Beth notes, "The students' enthusiasm has a tremendous influence on my practice of science." Likewise, Melissa writes, "Student engagement is always a driving factor for how I plan lessons."

Results from the Science Teachers' Efficacy Beliefs Instrument revealed that teachers in both the control and treatment groups experienced significant growth in their Personal Science Teaching Efficacy (PSTE). This was a surprising result, given that no interventions took place with the control group. With these results, it is unclear whether the professional development impacted teacher self-efficacy, or it if was something else. Once again, the number of participants in this study limits the ability to confirm that the professional development intervention was an effective intervention that increased self-efficacy. A larger scale study is necessary to investigate this further.

For the Science Teaching Outcome Expectancy (STOE) portion of the STEBI, no significant change was identified. As mentioned in the last chapter, although significant differences were not found between groups regarding change in the STOE portion of the STEBI, a clear trending difference was indicated when comparing means. Moreover, the strong correlation found between the STOE and change in teacher practice suggests that as teachers gain confidence and improve practice, they may change their views of their students' capabilities.

Finally some relationships were identified between components of this study. Using gain scores on several measures, significant correlations were found between lesson quality gains and student content gains. This result suggests that as teachers increase the quality of their lesson, student understanding increases. Another significant correlation was between change in the science teaching outcome expectancy portion of the self-efficacy survey and gain scores on the lesson quality observation protocol. These results suggest that as teachers increase their lesson quality, they may see an increase in the capabilities of their students. Finally, a marginally significant correlation was found between teacher self-efficacy and student content scores. These correlations further support the interconnectedness of the components of Guskey's professional development model.

Conclusions

The following section situates the findings of this study within current supporting research. The specifics of the professional development intervention in relation to the elements of effective professional development are highlighted. In addition, the results of this study in relation to Guskey's theoretical framework for professional development will be discussed.

Elements of Effective Professional Development

The professional development intervention experience for teachers was carefully planned and designed with specific research supported elements in mind. Research has identified several elements of effective professional development: focus on content, active participation, collaboration, cohesion, duration, and follow up (Birman et al., 2000; Desimone, 2009; Garet et al., 2001). Each element is presented in the context of the professional development intervention below. Although these elements are presented separately, the interaction and inclusion of all of these elements together contribute to making the professional development experience successful.

Content Knowledge

The focus on content did allow for teachers to solidify their understanding of the concepts in physical science. Although the content test gains for teachers were not significant, the fact that their students made significant gains indicates that the teachers were successful at communicating the content to students. Physical science concepts are perhaps the most challenging science concepts for elementary teachers. Elementary teachers have limited exposure to the variety of content they are expected to teach in a typical school year (Nowicki et al., 2013). Several comments were made in reflections that support how content knowledge impacts their confidence and ability to teach effectively. Melissa writes, "*I have a better understanding of physical science and what the labs are teaching, this helps me explain it to students.*" Including content knowledge in professional development experiences for teachers is essential to building concept understanding, and in turn improving practice, student outcomes, and self-efficacy.

Active Participation

Providing opportunities for teachers to actively participate appeared to be an important element for this science professional development experience. Each session involved teachers acting as students and working through labs and experiments.

Teachers overwhelmingly mentioned that being able to practice and try out activities was essential to their understanding and their abilities to implement the lessons in their own classrooms. Changing teacher practice, specifically the change to inquiry–based learning, is perhaps one of the most challenging changes for teachers to make (Penuel et. al., 2007). Providing teachers with opportunities to actively participate was an essential element that helped solidify their content knowledge and practice for teaching science.

Collaboration

Collaboration has gained strong momentum in the educational community in the last few decades (Desimone, 2009; Garet et. al., 2001). This professional development experience provided teachers with opportunities to share their experiences and learn from colleagues from other schools and districts who teach the same grade level. Changing practice is a challenging endeavor; having the support of colleagues who are also transforming practice provides a necessary support network.

Cohesion

The professional development intervention was developed with a specific grade level and curriculum in mind. Providing a specific stream-lined experience for teachers increases the likelihood that teachers will implement new practices (Guskey, 2002). Teachers who experienced the professional development intervention learned new practices that were perceived to be useful since they aligned to the curriculum they are required to teach.

Duration

Although the duration of this professional development experience was limited to seven three hour sessions, the specific focus on one content area and grade level allowed for a comprehensive experience. Research varies in the number of recommended hours for effective professional development from 15 hours to 80 (Supovitz & Turner, 2000; Yoon et al., 2007). Having a clear, specific, and cohesive focus may allow for an effective professional development of a shorter duration. This is something to keep in mind when designing professional development. Teachers are already over-worked and over-scheduled; having shorter but more focused professional development may be the answer to recruiting more teachers to participate in these opportunities.

Follow-Up

The final session of the professional development intervention took place a month after teachers had had the opportunity to implement their physical science unit within their classrooms. Group members shared successes and challenges, and brainstormed possible solutions to implementation challenges. Providing additional follow-up meetings throughout the next school year is a goal of the researcher of this project.

Complex Relationships between Professional Development Components

As noted in the results section, some interesting correlations were made between different components of Guskey's model. These correlations further support the notion that professional development is a complicated endeavor. Guskey's model follows a linear direction: Professional Development leads to a change in practice, which leads to a change in student outcomes, which leads to a change in teacher self-efficacy.

This study has revealed that these components may be connected in a more complicated manor, and may be more cyclical in nature (see Figure 18).

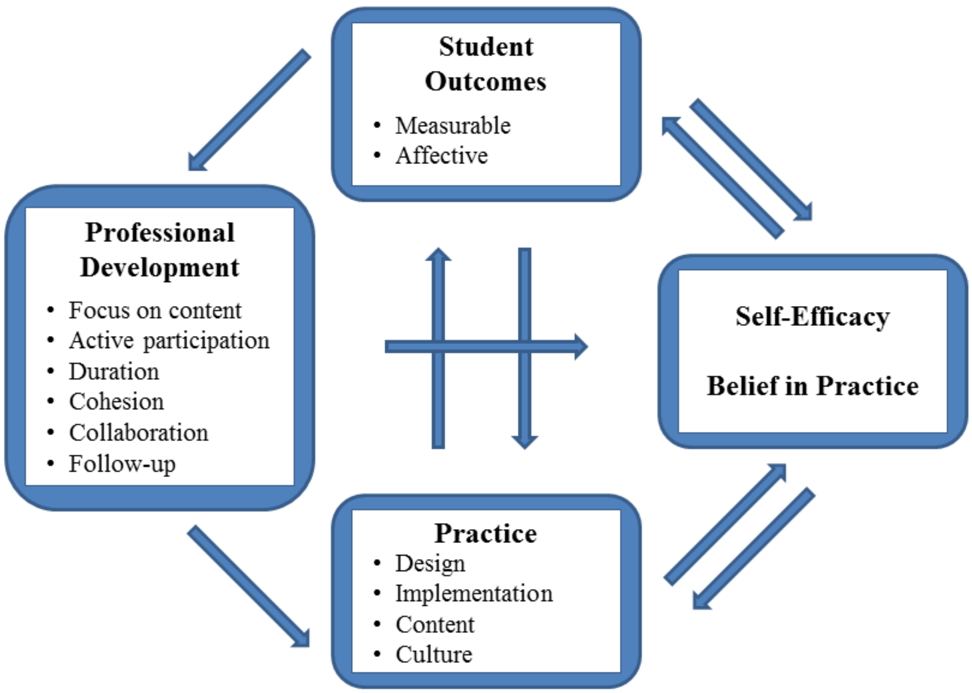

Figure 18. Adapted Model for Professional Development

Figure 18 above represents an adapted version of Guskey's model. The four major components are still present, but the directionality of impact varies. As evidenced from the arrows in the illustration, the impact can move in multiple directions from component to component.

To further explain the cycles, consider the following narrative describing how teachers in the experimental group may have experienced professional development in terms of the components in Figure 18: The teacher comes to the professional development and participates in an activity designed to teach the properties of matter. The following week, she tries the activity with her students (PD-Practice). She notices that her students are excited and engaged in the activity, so this motivates her to try out more inquiry-based lessons learned in the PD (Student Outcome-Practice). As the weeks progress, the teacher practices more hands on inquiry lessons during the PD, and she starts to feel more confident about teaching using this new practice (PD-Self-Efficacy). As her confidence continues to grow, she decided to adjust her practice even more by allowing the students to do a more open inquiry (Self-Efficacy-Practice).

The above scenario is to illustrate the cyclical nature of the professional development process. Once teachers learn a new practice, an iterative process begins as the teacher works to successfully implement and improve this practice.

Interestingly, student outcome data may not need to take the form of traditional data such as test scores and engagement survey scores. Teachers, especially elementary teachers, respond to student behaviors that indicate engagement and enjoyment. These anecdotal observations may be all that is needed to encourage teachers to continue to implement and refine new practices.

One new component in this adapted model is the component of beliefs. Beliefs in this model refer to beliefs in a specific practice. Although this study did not use a tool to measure these beliefs empirically, anecdotes from teacher reflections support the notion that teachers developed beliefs in the effectiveness of the new practices they were implementing. Video recorded lessons also support this conception in that all teachers in the experimental group implemented a practice or idea gleaned from the professional development in their post video, even though they were not asked or required to do so. This suggests they believed the instructional approach would be effective with their students. In order for teachers to implement new practices, and continue to implement new practices, they must believe in the effectiveness of such practices. It would be interesting to follow up with the teachers in the next school year to see if they are still implementing practices learned in the professional development intervention. The ultimate success of professional development lies in the lasting impacts to practice.

Limitations

<u>Participants</u>

The main limitation to this study involves the small number of participants. Trying to find elementary teachers to give up their evenings to improve science instruction was challenging. The small number of participants also made it difficult to find significance on teacher measures. Even for the measures where significance was found, the limited number of participants makes it difficult to generalize to the population.

In addition, the self-selected nature of the participants suggests that these teachers most likely enjoy teaching science. This group of teachers was probably not typical with regards to science teaching knowledge, confidence in science, and desire to teach science.

<u>Reliability of Measures</u>

Reliability on some of the measures used in this study was low. In particular, the internal consistency reliability for the LSC protocol was very low for the culture component. Providing training for the raters may have helped to mitigate this issue.

Directions for Future Research

Through this study, an appreciation regarding the complex nature of the impacts of professional development has resulted in a desire to look more closely at specific components and elements.

Concerning the elements of successful professional development, a deeper focus on active participation in the area of acquiring science content knowledge and pedagogy would help develop more effective professional development experiences for teachers. This element was arguably the most impactful element of the professional development experience for the teachers in this study. Connecting active participation and the acquisition of content knowledge in science would also be an interesting direction for future research. Specifically, investigating how different levels of active participation impact content knowledge and practice would be compelling.

Another area for future research involves examining the relationship of teacher misconceptions in science and students' misconceptions in science. Investigating how these misconceptions are passed on from teacher to student and the processes for clarifying misconceptions at different age levels in science would benefit the research community as well as students and teachers.

Since increasing the quality and quantity of science instruction at the elementary level has been the goal of this project, it would make sense to investigate teacher preparation programs and their role in preparing future elementary science teachers. Implementing rigorous science methods experiences that incorporate the elements identified in successful professional development could provide valuable contributions to the area of improving pre-service teacher preparation in elementary science. Using similar tools to measure content knowledge, lesson quality, and self-efficacy before and after these courses could provide valuable evidence to support systemic changes in teacher preparation.

Finally, a larger scale version of this study could reveal more intricate relationships between components. Providing all teachers, including those that are reluctant to teach science, with a professional development opportunity similar to the intervention in this study may lead to a larger, and clearer impact. Providing opportunities as such, embedded in the regular work day would be ideal.

Hilda Borko (2004) supports the idea of scaling up with professional development. Once successful elements have been identified in smaller scale projects, the next logical step would be to scale up to a larger version of the professional development. Moving from a small workshop of 11 teachers to perhaps a district-wide effort including all fifth grade teachers in the district would be an interesting trajectory that may provide meaningful data to further support and define the findings of this project. The likelihood of finding significance in areas of this study where significance was not found would likely increase with a larger number of participants. Train the trainer models would also be an interesting extension to this project that would allow for scaling up. Collecting data on the effectiveness of the professional development implementation as it is passed from trainer to new trainer would be an interesting direction for future research.

Final Thoughts

Science instruction in elementary schools is a rare occurrence for a variety of reasons, including, but not limited to, a lack of time, a lack of materials, and a lack of confidence. Effective professional development may be an effective conduit to improve this unfortunate situation. By understanding the complicated elements and components involved in the process of teacher learning and change, professional development providers can support teachers with the tools and experiences to make this transformation a reality, and ultimately impact our students in positive ways.

Providing school districts with evidence of successful professional development may exhort districts to invest the money needed to provide their teachers with quality professional development in the area of science instruction. Our society is in critical need of STEM focused workers. Providing early exposure to science through instructional best practices at the elementary grades such as inquiry and integrated STEM will pay dividends in the future.

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APPENDIX A

Participant Recruitment Process

October 2014:

After a research proposal was reviewed and approved by school districts, an initial letter was emailed to elementary principals with an attached flyer to be distributed to the fifth grade teachers at their schools. This email was sent several times to some schools if no responses occurred within a few weeks.

November-December 2014

Interested teachers contacted the researcher directly, and an initial date and meeting place was scheduled.

January, 2014

Participants met for an initial meeting at one of the school sites. Consent forms were signed at this time and a briefing of the project was shared. Teachers were assigned to either the control or treatment group and initial videos were scheduled.

Initial Email to Principals

I am writing to tell you about an exciting professional development opportunity available to 5th grade teachers from your school. This project is a professional development project specifically for 5th grade teachers focused on inquiry based integrated lessons to improve the quality of science instruction. A comprehensive integrated physical science unit will be enhanced with common core math concepts, as well as common core ELA concepts where appropriate. The professional development project will be developed with research based elements of effective professional development in mind. Other areas of focus will be to increase content knowledge of teachers and facilitate a collaborative environment for unit development.

Teachers will be given science kits and the opportunity to engage in hands-on inquiry lessons that they can utilize in their own classrooms. Two continuing education credits will also be available for teachers assigned to the experimental group.

I am attaching a flyer for you to share with your fifth grade team. If you would like more information on this project, please contact me via email or at the phone number below. I would be happy to visit with you and any interested 5th grade teachers to provide more details. Thanks for your time,

Sincerely,

Jan Smith

949-4877

Teacher Flyer

Attention 5th Grade Teachers!

You are cordially invited to participate in a research project focused on developing an integrated physical science unit specifically designed to match the fifth grade curriculum and standards.

Due to the experimental nature of the project, if you choose to participate, you will be randomly assigned to either the professional development group or the control group.

Professional Development Group Requirements:

1. Participate in 7 three hour workshops
   - survey data will be collected both before and after the workshops
2. Record a science lesson both before and after the workshop.
3. Administer pre and posttests to your students.

***As compensation for your participation you will receive 2 continuing education credits and one science kit valued at $150. You will also gain a plethora of amazing ideas to integrate physical science with common core math and common core ELA. ***

Control Group Requirements

1. Take 2 surveys; one in January and one in May
2. Record 2 science lessons, one in January and one in May
3. Administer pre and posttests to your students.

***As compensation for your participation you will receive a science kit valued at $150. ***

Space is limited! If you are interested, please email janettesmith@boisestate.edu

APPENDIX B

Sample Lesson Plans and Activities from Professional Development Intervention

Movin' Molecules

Grade Level: 5

Lesson Source: www.inquiryinaction.og

Concepts: Movement and arrangement of molecules varies within different states of matter.

Objectives:

SWBAT demonstrate that molecules move differently in cold water, warm water, and ice.
SWBAT physically model how molecules are arranged in a solid, liquid, and gas.

Idaho State Standards: (science)

5.S.1.2.1 Use observations and data as evidence on which to base scientific explanations and predictions
5.S.1.2.3 Use models to explain or demonstrate a concept.
5.S.1.6.5 State a hypothesis based on observations.
5.S.1.6.7 Communicate scientific procedures and explanations.
5.S.2.1.2 Compare the physical differences among solids, liquids and gases.

Materials List and Advanced Preparations:

For Demo:
Hot pot
Pan with water
Pie plate
Ice cubes
Pot holder

For Activity:
Plastic cups; one filled with cold water, one filled with hot, one filled with ice
Food coloring
Hot pot for heating water
Trays for cups for each pair.

Safety:

Be careful of the hot water.
Be careful with food coloring; it stains clothes

ENGAGEMENT		Time: Minutes
What theTeacher Will Do	**Probing/Eliciting Questions**	**Student Responses and Misconceptions**
Teacher boils water using a hot pot.	I’ve got some water boiling here. Talk with the person next to you about what is happening.	
	What did you discuss?	The water is turning into a gas?
	What is causing the change from liquid to gas?	The heat.
So we all agree that when the water molecules are heated up, they turn into a gas. This is called evaporation.	What would happen if I cooled the gas down?	It might turn back into water.
I’m going to continue to boil the water, but now I’m going to hold a pie plate with ice cubes above the gas.	What do you notice?	Little droplets of water are forming on the pie plate. The gas is turning back into water.
Yes! The gas is condensing back into water when it is cooled.		

EXPLORATION		**Time: Minutes**
What the Teacher Will Do	**Probing/Eliciting Questions**	**Student Responses and Misconceptions**
Today we are going to investigate the states of matter and how molecules move in each. You and your partner will get 3 cups. One has hot water, one has cold water, and one has ice. You will add a drop of food coloring to each and observe what happens. Before materials are collected, fill in a hypothesis for this experiment on the activity sheet.		
Movement of Molecules Activity She		
Be careful of the hot water. Also be careful not to get the food coloring on your clothes because it won't come out.		
Students begin the activity.	What do you notice?	The food coloring is moving really slowly through the ice.
	Why do you think that is so? What is making it move so slow?	It's hard to get through a solid.
	What's happening in the warm water?	The food coloring is spreading out really fast.
	What does that suggest about how the molecules are moving in the warm water?	They are moving fast. They might be more spread out so that the food coloring can get through.
	So even though we can't put food coloring in a gas, based on what you've done with the solid, the cold water, and the warm water, how do you think the molecules are	They are probably moving fast and are more spread out.

	arranged in a gas? Think about the demo we did at the beginning of the lesson with the boiling water.	

EXPLANATION		**Time: Minutes**
What the Teacher Will Do	**Probing/Eliciting Questions**	**Student Responses and Misconceptions**
Ok, we are going to return all the cups and food coloring to the materials collection area and head back to our seats to discuss results.	Who wants to share what happened in the experiment?	Different students will share out results of the experiments
	So in thinking about the molecules in each of the states of matter, how does this experiment suggest that they are arranged? Talk in your groups for a few minutes and share some ideas.	
	Which group would like to share ideas?	We think the molecules in a solid are close together. This is why it was so hard for the food coloring to move around. We also think the molecules in a liquid are more spread out. As the liquid got warmer, they spread out even more.
	What about a gas? We couldn't put food coloring in a gas, but we can still predict how the molecules might be arranged in a gas.	I think they are really spread out and moving quickly.

ELABORATION		Time: Minutes
What the Teacher Will Do	**Probing/Eliciting Questions**	**Student Responses and Misconceptions**
To emphasize what we've just learned, we are going to use our bodies to imitate molecules in each of the states of matter.	We need six students to act out a solid. Who wants to come up and show us how you would be arranged and how you would act.	Students come up and squish close together.
Since the molecules are so tightly arranged, they can't really move around too much in a solid. They basically will just vibrate a little.		Students shake a little to model the solid molecules.
	Who wants to come up and act out the molecules in a liquid?	6 different students come up and act out a liquid.
Molecules in a liquid are more spread out and can move around between each other a little.		Students move around a little in between each other.
	Ok, now we need 6 students to act out a gas. Since there is no container, you would have the whole room.	Students come up and then begin running around the room.
	What happens when the gas hits this wall?	It bounces off and heads in a different direction.
That's right. Molecules in a gas are more spread out and moving quickly.		

EVALUATION		Time: Minutes
What the Teacher Will Do	**Probing/Eliciting Questions**	**Student Responses and Misconceptions**
Students write a paragraph about what they learned today. They should include something about how molecules are arranged in a solid, liquid, and gas.		

Chemistry in a Bag

Grade Level: 5

Concepts: Chemical changes are changes that change the properties of a substance and actually change the substance into something different. Common signs of a chemical change include a color change, a heat change, or a release of gases.

Objectives:

SWBAT conduct a simple experiment and observe different kinds of evidence that indicate a chemical change.
SWBAT create their own experiment to determine which chemicals produced which evidence. ‘

Idaho State Standards:

5.S.1.2.1 Use observations and data as evidence on which to base scientific explanations and predictions.
5.S.1.6.1 Write and analyze questions that can be answered by conducting scientific experiments.
5.S.1.6.5 State a hypothesis based on observations.
5.S.1.6.6 Compare alternative explanations and predictions.
5.S.1.6.7 Communicate scientific procedures and explanations.

Materials List and Advanced Preparations:

Demo: Paper, a lighter/Legos for elaboration

Phenol Red (20 ml’s per pair)
Calcium Chloride
Baking soda
Ziploc baggies
Small cups with lids
Safety goggles

Safety:

Calcium chloride is a chemical that can irritate your eyes; try not to touch it.

ENGAGEMENT		Time: Minutes
What the Teacher Will Do	**Probing/Eliciting Questions**	**Student Responses and Misconceptions**
Hold up a piece of paper.	What is this?	A piece of paper.
Tear up the paper into four pieces.	Now what are these?	Still paper.
I've changed the paper, but the changes I made didn't change the fact that these pieces are still paper.	What kind of change do you think that is? How else could I change this paper?	A physical change. You could crumple it up. You could burn it.
(If no one suggests burning the paper, I will)	What do you think will happen if I burn the paper?	It will turn grey. It will make ash.
Burn a piece of paper and hold it up with tweezers over a bowl.	What do you notice?	There's a bunch of ash.
Is it still paper?		No.
Since it is no longer paper it has changed into something else.	This type of change is called a chemical change because the chemical makeup of the paper has changed.	
Today we are going to do some experiments. You can decide with your partner if you think they produce a physical change or a chemical change.		

EXPLORATION		Time: Minutes
What the Teacher Will Do	**Probing/Eliciting Questions**	**Student Responses and Misconceptions**
For today's experiment, you will combine 3 different substances in a Ziploc bag and record any observations you notice. After you combine the different substances, you will decide if you think a chemical change has occurred or a physical change has occurred.		
Here are the substances. (Hold up each)	Does anyone have any guesses as to what these	Baking soda.

	substances are?	
Today we are working with baking soda, calcium chloride, and a substance called Phenol Red. We need to use our science safety rules today. We will be using safety goggles, and you are not to touch the calcium chloride if possible. Also, the phenol red can stain your clothes so be careful. Before we start let's go over the activity sheet. Chemistry in a bag.pdf	Does anyone have any questions about what you are supposed to do? Who can repeat the directions to everyone?	
Students will begin the experiment	What kind of changes did you notice?	It changed color
	What else?	There's gas being released
	What evidence do you have that gas is being released?	The bag is filling up with a gas.
	Do you think you are witnessing a physical change or a chemical change?	
(Teacher gains attention of the class once everyone finishes part one of the experiment.) You've witnessed several different reactions in one experiment. Your job now is to conduct more experiments to see if you can determine what two reactants are causing the different changes.	What is causing the heat? What is causing the gas? Talk with your partner to discuss a plan for finding this out.	Students conduct more experiments only combining two substances.

EXPLANATION		Time: Minutes
What the Teacher Will Do	**Probing/Eliciting Questions**	**Student Responses and Misconceptions**
	What kind of reactions did you notice when you combined all three substances?	The bag filled with air.
	Do you think it was air? What else could it have been?	Any gas
	What else did you notice?	It turned orange
	Anything else? Did anyone else have a different result?	It got very hot.
	For the second experiment, who wants to share what substances you decided to combine? Tell us what happened.	Various pairs share out their experiments.
Now that different students have shared their results, talk with your partner to come up with an overall conclusion for today's experiment Students talk for a few minutes and then we discuss as a group what caused the heat, what caused the gas, and what caused the color change.	What did you find out?	They should conclude that calcium chloride and water or phenol red produce heat. They also should conclude that phenol red with either the baking soda or calcium chloride makes a color change. Finally, mixing baking soda and calcium chloride with a liquid is necessary to produce the gas.
What kind of changes do you think we witnessed today, physical or chemical?		Chemical
How do you know?		The substances became something different.

ELABORATION		Time: Minutes
What the Teacher Will Do	**Probing/Eliciting Questions**	**Student Responses and Misconceptions**
Show Lego models under the document camera showing the original substances rearranging to make new substances.	Did we use all the same pieces? Were any leftover? Are these new substances?	Yes No Yes
BakingSodaCalciumChlorideMats2.0.pdf		

EVALUATION		Time: Minutes
What the Teacher Will Do	**Probing/Eliciting Questions**	**Student Responses and Misconceptions**
Students write a paragraph explaining how they can tell when something has undergone a chemical change.		

APPENDIX C

LSC Observation Protocol

I. Design

A. Ratings of Key Indicators

	Not at all				To a great extent	Don't know	N/A
1. The design of the lesson incorporated tasks, roles, and interactions consistent with investigative mathematics/science.	1	2	3	4	5	6	7
2. The design of the lesson reflected careful planning and organization.	1	2	3	4	5	6	7
3. The instructional strategies and activities used in this lesson reflected attention to students' experience, preparedness, and/or learning styles.	1	2	3	4	5	6	7
4. The resources available in this lesson contributed to accomplishing the purposes of the instruction.	1	2	3	4	5	6	7
5. The instructional strategies and activities reflected attention to issues of access, equity, and diversity for students (e.g., cooperative learning, language-appropriate strategies/materials).	1	2	3	4	5	6	7
6. The design of the lesson encouraged a collaborative approach to learning.	1	2	3	4	5	6	7
7. Adequate time and structure were provided for "sense-making."	1	2	3	4	5	6	7
8. Adequate time and structure were provided for wrap-up.	1	2	3	4	5	6	7
9. Formal assessments of students were consistent with investigative mathematics/science.	1	2	3	4	5	6	7
10. Design for future instruction takes into account what transpired in the lesson.	1	2	3	4	5	6	7
11. ______________________________	1	2	3	4	5		

B. Synthesis Rating

1	2	3	4	5
Design of the lesson not at all reflective of best practice in mathematics/science education				Design of the lesson extremely reflective of best practice in mathematics/science education

II. Implementation

A. Ratings of Key Indicators

	Not at all				To a great extent	Don't know	N/A
1. The instruction was consistent with the underlying approach of the instructional materials designated for use by the LSC.	1	2	3	4	5	6	7
2. The instructional strategies were consistent with investigative mathematics/science.	1	2	3	4	5	6	7
3. The teacher appeared confident in his/her ability to teach mathematics/science.	1	2	3	4	5	6	7
4. The teacher's classroom management style/strategies enhanced the quality of the lesson.	1	2	3	4	5	6	7
5. The pace of the lesson was appropriate for the developmental levels/needs of the students and the purposes of the lesson.	1	2	3	4	5	6	7
6. The teacher was able to "read" the students' level of understanding and adjusted instruction accordingly.	1	2	3	4	5	6	7
7. The teacher's questioning strategies were likely to enhance the development of student conceptual understanding/problem solving (e.g., emphasized higher order questions, appropriately used "wait time," identified prior conceptions and misconceptions).	1	2	3	4	5	6	7
8. The lesson was modified as needed based on teacher questioning or other student assessments.	1	2	3	4	5	6	7
9. ______________________________	1	2	3	4	5		

B. Synthesis Rating

1	2	3	4	5
Implementation of the lesson not at all reflective of best practice in mathematics/science education				Implementation of the lesson extremely reflective of best practice in mathematics/science education

III. Mathematics/Science Content

A. Ratings of Key Indicators	Not at all				To a great extent	Don't know	N/A
1. The mathematics/science content was significant and worthwhile.	1	2	3	4	5	6	7
2. The mathematics/science content was appropriate for the developmental levels of the students in this class.	1	2	3	4	5	6	7
3. Students were intellectually engaged with important ideas relevant to the focus of the lesson.	1	2	3	4	5	6	7
4. Teacher-provided content information was accurate.	1	2	3	4	5	6	7
5. The teacher displayed an understanding of mathematics/science concepts (e.g., in his/her dialogue with students).	1	2	3	4	5	6	7
6. Mathematics/science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation analysis, and/or proof/justification.	1	2	3	4	5	6	7
7. Elements of mathematical/science abstraction (e.g., symbolic representations, theory building) were included when it was important to do so.	1	2	3	4	5	6	7
8. Appropriate connections were made to other areas of mathematics/ science, to other disciplines, and/or to real-world contexts.	1	2	3	4	5	6	7
9. The degree of "sense-making" of mathematics/science content within this lesson was appropriate for the developmental levels/needs of the students and the purposes of the lesson.	1	2	3	4	5	6	7
10. ______________________________	1	2	3	4	5		

B. Synthesis Rating

1	2	3	4	5
Mathematics/science content of lesson not at all reflective of current standards for mathematics/science education				Mathematics/science content of lesson extremely reflective of current standards for mathematics/science education

IV. Classroom Culture

A1. Ratings of Key Indicators

	Not at all				To a great extent	Don't know	N/A
1. Active participation of all was encouraged and valued.	1	2	3	4	5	6	7
2. There was a climate of respect for students' ideas, questions, and contributions.	1	2	3	4	5	6	7
3. Interactions reflected collegial working relationships among students (e.g., students worked together, talked with each other about the lesson).	1	2	3	4	5	6	7
4. Interactions reflected collaborative working relationships between teacher and students.	1	2	3	4	5	6	7
5. The climate of the lesson encouraged students to generate ideas, questions, conjectures, and/or propositions.	1	2	3	4	5	6	7
6. Intellectual rigor, constructive criticism, and the challenging of ideas were evident.	1	2	3	4	5	6	7
7. ______________________________	1	2	3	4	5		

A2. Respect for Diversity

Based on the culture of a classroom, observers are generally able to make inferences about the extent to which there is an appreciation of diversity among students (e.g., their gender, race/ethnicity, and/or cultural background). While direct evidence that reflects particular sensitivity or insensitivity toward diversity is not often observed, we would like you to document any examples you do see. If any examples were observed, please check here ☐ and describe below:

B. Synthesis Rating

1	2	3	4	5
Classroom culture interfered with student learning				Classroom culture facilitated the learning of all students

APPENDIX D

Student Scores Shared with Teachers and Their Explanations

Information on Student Assessments

Content Misconceptions Test

These tests were actually developed for middle school students and are based on common misconceptions. The assessment items are the result of more than a decade of research and development by Project 2061, a long-term science education reform initiative of the American Association for the Advancement of Science.

Science Attitudes Test

This test was developed to measure a student's attitude around science. Scores in five areas are derived from the 25 question test.

Perception of Science Teacher

Anxiety Toward Science

Value of Science in Society

Self-Concept of Science

Desire To Do Science.

On the survey, I accidentally made the scale backward (1-Strongly agree and 5 for Strongly disagree). All this does is reverse the number: So a lower number indicates more positive attitudes, with the exception of anxiety. Here the higher number indicates less anxiety.

Let me know if you have any questions on any of this data!

Content Misconception Scores

Student ID	Pre	Post
	50%	50
	60%	65
	35%	75
	30%	25
	45%	70
	20%	70
	40%	90
	44%	37
	25%	35
	15%	50
	30%	70
	35%	60
	50%	65
	55%	40
	35%	55
	25%	50
	25%	35
	50%	50
	50%	95
	30%	35
	35%	55
	60%	60
	20%	35
	33%	35
Average	37%	54.46

*Student ID numbers have been removed to protect privacy.

Student ID	Science Attitude Scores Pre					Science Attitude Score Post				
	Percep	Anxiety	Value	self-con	Desire	Percep	Anxiety	Value	self-con	Desire
	3.33	3.00	3.00	3.00	4.00	2.50	3.40	3.20	2.40	4.43
	1.33	4.75	1.60	2.40	1.43	1.00	5.00	1.00	1.60	1.14
	3.00	4.60	1.40	2.60	1.86	2.67	4.60	1.60	2.60	2.29
	1.67	4.40	1.20	2.20	2.14	2.33	4.60	1.80	1.80	2.57
	2.00	4.00	1.20	2.40	2.71	2.00	4.20	1.60	2.40	2.29
	1.67	4.00	2.00	2.40	2.86	1.67	4.60	1.40	1.60	2.71
	1.67	4.80	1.60	2.00	1.86	2.33	3.80	1.80	2.20	1.71
	1.67	4.20	1.40	2.60	2.14	1.67	3.60	1.60	2.20	1.83
	1.67	4.60	1.80	1.80	2.57	1.67	4.40	1.80	2.40	2.71
	1.33	4.00	1.80	1.60	1.86	1.00	4.20	1.20	1.20	1.29
	2.00	4.40	1.80	2.00	2.29	1.33	4.40	1.20	1.80	2.29
	1.00	4.40	2.00	1.60	1.43	1.33	5.00	1.60	2.00	1.71
	2.33	4.20	1.20	1.60	1.14	5.00	4.40	1.40	2.40	1.71
	2.00	5.00	1.20	2.60	1.86	1.00	4.60	1.20	2.00	1.71
	2.00	4.20	1.80	1.40	1.86	1.33	5.00	1.80	1.80	1.86
	2.33	3.60	1.60	2.40	3.14	3.00	3.20	2.00	2.60	3.86
	1.67	3.80	1.80	2.80	2.00	2.33	4.80	1.40	3.20	1.86
	1.00	4.60	1.20	1.20	2.00	1.67	4.40	1.25	1.00	1.86
	1.00	4.40	1.20	2.40	1.43	1.67	2.80	1.40	2.80	3.14
	2.33	4.40	1.40	1.60	2.86	2.67	4.80	1.40	1.40	2.43
	1.00	3.40	2.00	2.00	1.86	1.00	4.60	1.40	1.40	1.86
	1.33	5.00	1.00	1.20	1.14	1.67	5.00	1.40	1.40	1.29

*Student ID numbers have been removed to protect privacy.

APPENDIX E

IRB Approval and Supporting Consent Forms

BOISE STATE UNIVERSITY
RESEARCH AND ECONOMIC DEVELOPMENT

Date: January 20, 2015

To: Janette Smith cc: Keith Thiede

From: Social & Behavioral Insitutional Review Board (SB-IRB)
c/o Office of Research Compliance (ORC)

Subject: SB-IRB Notification of Approval - Original - 101-SB14-179
Transformative Professional Development

The Boise State University IRB has approved your protocol submission. Your protocol is in compliance with this institution's Federal Wide Assurance (#0000097) and the DHHS Regulations for the Protection of Human Subjects (45 CFR 46).

Protocol Number:	**101-SB14-179**	Received:	12/18/2014	Review:	Expedited
Expires:	**1/19/2016**	Approved:	1/20/2015	Category:	6, 7

Your approved protocol is effective until 1/19/2016. To remain open, your protocol must be renewed on an annual basis and cannot be renewed beyond 1/19/2018. For the activities to continue beyond 1/19/2018, a new protocol application must be submitted.

ORC will notify you of the protocol's upcoming expiration roughly 30 days prior to 1/19/2016. You, as the PI, have the primary responsibility to ensure any forms are submitted in a timely manner for the approved activities to continue. If the protocol is not renewed before 1/19/2016, the protocol will be closed. If you wish to continue the activities after the protocol is closed, you must submit a new protocol application for SB-IRB review and approval.

You must notify the SB-IRB of any additions or changes to your approved protocol using a Modification Form. The SB-IRB must review and approve the modifications before they can begin. When your activities are complete or discontinued, please submit a Final Report. An executive summary or other documents with the results of the research may be included.

All forms are available on the ORC website at http://goo.gl/D2FYTV

Please direct any questions or concerns to ORC at 426-5401 or humansubjects@boisestate.edu.

Thank you and good luck with your research.

Mary E. Pritchard

Dr. Mary Pritchard
Chair
Boise State University Social & Behavioral Insitutional Review Board

Informed Consent

BOISE STATE UNIVERSITY

INFORMED CONSENT

Study Title: Transformative Professional Development
Principal Investigator: Janette Smith **Co-Investigator:** Dr. Keith Thiede

This consent form will give you the information you will need to understand why this research study is being done and why you are being invited to participate. It will also describe what you will need to do to participate as well as any known risks, inconveniences or discomforts that you may have while participating. We encourage you to ask questions at any time. If you decide to participate, you will be asked to sign this form and it will be a record of your agreement to participate. You will be given a copy of this form to keep.

➢ **PURPOSE AND BACKGROUND**

The purpose of this research is to examine the impacts of a science professional development opportunity on content knowledge, practice and teachers' self-efficacy. In addition this study seeks to investigate the impacts of the professional development on the student of the teacher participants. You are being asked to participate because you are a fifth grade teacher, and this project focuses specifically on the 5th grade curriculum for physical science.

➢ **PROCEDURES**

If you agree to be in this study, you will participate in the following:

- Pre and Posttest on science content knowledge for physical science
- Pre and post survey on self-efficacy beliefs for teaching science
- Video recordings of two science lessons; one before the study and one after.
- Administering pre and posttest to your students
- Administering a pre and post engagement survey to your students

- In addition, if you are randomly assigned to the treatment group, you will participate in 7 three hour professional development meetings. Part of this professional development process will include keeping a reflective journal. Prompts will be provided to guide your reflections.

➢ **RISKS**

The observation protocol data sheet will include a section requesting demographic information. Due to the make-up of Idaho's population, the combined answers to these questions may make an individual person identifiable. We will make every effort to protect participants' confidentiality. However, if you are uncomfortable answering any of these questions, you may leave them blank.

In the unlikely event that some of the survey questions or the recording of your lessons make you uncomfortable or upset, you are always free to decline to answer or to stop your participation at any time. Should you feel discomfort after participating you should contact your health care provider.

➢ **BENEFITS**

By participating in this study you will receive a science kit of materials to use in your own classrooms. In addition, your science teaching practices may improve as a result of participating in this study. Finally the information that you provide throughout this study may benefit future professional developers as they work to create effective professional development opportunities for teachers.

In addition, if you are randomly assigned to the treatment group, you will be eligible for 2 continuing education credits through Boise State University.

➢ **EXTENT OF CONFIDENTIALITY**

Reasonable efforts will be made to keep the personal information in your research record private and confidential. Any identifiable information obtained in connection with this study will remain confidential and will be disclosed only with your permission or as required by law. The researcher and the Boise State University Office of Research Compliance (ORC) may access the data. The ORC monitors research studies to protect the rights and welfare of research participants.

Your name will not be used in any written reports or publications which result from this research. In the event of a publishable paper, pseudonyms will be used to protect your identity. Data will be kept for three years (per federal regulations) after the study is complete and then destroyed.

➢ **PAYMENT**

You will not be paid for your participation in this study.

➢ **PARTICIPATION IS VOLUNTARY**

You do not have to be in this study if you do not want to. You may also refuse to answer any questions you do not want to answer. If you volunteer to be in this study, you may withdraw from it at any time without consequences of any kind or loss of benefits to which you are otherwise entitled.

➢ **QUESTIONS**

If you have any questions or concerns about your participation in this study, you may contact the Principal Investigator, Janette Smith at (208) 949-4877 or by emailing janettesmith@boisestate.edu., or the co-principal investigator, Dr. Keith Thiede at (208) 426-1278, or by emailing keiththiede@boisestate.edu.

If you have questions about your rights as a research participant, you may contact the Boise State University Institutional Review Board (IRB), which is concerned with the protection of volunteers in research projects. You may reach the board office between 8:00 AM and 5:00 PM, Monday through Friday, by calling (208) 426-5401 or by writing: Institutional Review Board, Office of Research Compliance, Boise State University, 1910 University Dr., Boise, ID 83725-1138.

OCUMENTATION OF CONSENT

have read this form and decided that I will participate in the project described above. Its general purposes, ıe particulars of involvement and possible risks have been explained to my satisfaction. I understand I can ıithdraw at any time.

Printed Name of Study Participant | **Signature** of Study Participant | Date

Parental Consent

BOISE STATE UNIVERSITY

INFORMED CONSENT

Study Title: Transformative Professional Development
Principal Investigator: Janette Smith **Co-Principal Investigator**: Dr. Keith Thiede

Dear Parent/Guardian:

My name is Janette Smith and I am a doctoral student in the Curriculum and Instruction program at Boise State University. I am asking for your permission to include your child in my research. This consent form will give you the information you will need to understand why this study is being done and why your child is being invited to participate. It will also describe what your child will need to do to participate as well as any known risks, inconveniences or discomforts that your child may have while participating. I encourage you to ask questions at any time. If you decide to allow your child to participate, you will be asked to sign this form and it will be a record of your agreement to participate. You will be given a copy of this form to keep.

- **PURPOSE AND BACKGROUND**

The purpose of this study is to investigate the impacts of a science professional development intervention for 5^{th} grade teachers. Due to the experimental nature of this study, some participating teachers will receive professional development for science instruction and some will not. This study hopes to investigate the impacts on both teachers and students.

- **PROCEDURES**

This study will include an observation of science instruction in your child's class. Your child will be asked to take both a pre and post-test for the physical science unit, similar to tests the teacher would typically administer. In addition, your child will be asked to take a pre/post survey on their engagement in science. If you choose not to allow your child to participate, s/he will remain in their classroom, but they will not be videotaped and copies of their tests and surveys will not be analyzed.

Your child's classroom will be videotaped twice during the next few months. Your child will be videotaped in their normal classroom during normal course activities. It is estimated that the research study will take approximately 2 months to complete. At no time will your child be separated from peers or the teachers.

- **RISKS/DISCOMFORTS**

Your child may feel uncomfortable being videotaped, but the camera will be placed in a matter that should not distract them. You can ask for your child not to be taped at any time. Your child may also ask not to be taped at any time. You are able to remove your child from the study at any time and your child will continue to receive quality instruction in this classroom.

- **EXTENT OF CONFIDENTIALITY**

Reasonable efforts will be made to keep the personal information in your research record private and confidential. Any identifiable information obtained in connection with this study will remain confidential and will be disclosed only with your permission or as required by law. The researcher and the Boise State University Office of Research Compliance (ORC) may access the data. The ORC monitors research studies to protect the rights and welfare of research participants.

Your child's name will not be used in any written reports or publications which result from this research. Data will be kept for three years (per federal regulations) after the study is complete and then destroyed.

- **BENEFITS**

Your child may benefit from participating in this study by receiving enhanced instruction in physical science. Your child may also benefit by being more engaged in hands on science instruction. In addition, the information gained from this research may help education professionals better understand how to successfully design effective teacher professional development.

- **PAYMENT**

There will be no payment to you or your child as a result of your child taking part in this study.

- **QUESTIONS**

If you have any questions or concerns about participation in this study, you should first talk with the principal investigator Janette Smith at (208)949-4877 or email janettesmith@boisestate.edu. You may also contact the co-principal investigator, Dr. Keith Thiede at (208) 426-1278 or email keiththiede@boisestat.edu.

If you have questions about your child's rights as a research participant, you may contact the Boise State University Institutional Review Board (IRB), which is concerned with the protection of volunteers in research projects. You may reach the board office between 8:00 AM and 5:00 PM, Monday through Friday, by calling (208) 426-5401 or by writing: Institutional Review Board, Office of Research Compliance, Boise State University, 1910 University Dr., Boise, ID 83725-1138.

DOCUMENTATION OF CONSENT

I have read this form and decided that my child will participate in the project described above. Its general purposes, the particulars of involvement and possible risks have been explained to my satisfaction. I will discuss this research study with my child and explain the procedures that will take place. I understand I can withdraw my child at any time.

____

Printed Name of Child

By signing this form, you also indicate that you have discussed this project with your child.

Printed Name of Parent/Guardian	**Signature** of Parent/Guardian	Date
Signature of Person Obtaining Consent		Date

APPENDIX F

Sample Content Misconceptions Test Items

Let's Get Physical

1. The windows of your school are made of glass. Which of the following statements describes the motion of the molecules that make up the glass?

   A. The molecules of the glass are never moving.
   B. The molecules of the glass are always moving.
   C. The molecules of the glass only move when the sun warms the window.
   D. The molecules of the glass only move when the window is being opened and closed.

2. A cook takes a hot iron frying pan off the stove to cool. What happens as the iron pan cools?

   A. The mass of the iron atoms increases, so the pan gets a tiny bit heavier.
   B. The mass of the iron atoms does not change, so the pan remains the same.
   C. The distance between the iron atoms decreases, so the pan gets a tiny bit smaller.
   D. The distance between the iron atoms does not change, so the pan remains the same.

3. Which of the following is the smallest?

   A. A germ
   B. An atom
   C. The width of a hair
   D. A cell in your body

APPENDIX G

Teacher Reflection Prompts

First Reflection: Prior to professional development intervention

Reflecting on Science Instruction

How would you describe your knowledge and understanding of physical science content? What effect does your knowledge and understanding have on your science teaching?

Describe your confidence for teaching science. What affects your confidence in teaching science?

With your current teaching practices for teaching science, what do you notice about your students?

What is your name?

What is the date?

Middle Reflection Prompt: Administered after 4 workshops

Reflection Prompts: Mid Way

What have you learned in the professional development thus far? Has it changed the way you teach physical science or think about teaching science?

Have you noticed any changes in your students as a result of changes in the way you teach science? How do these changes influence your confidence for teaching physical science?

Describe your confidence in teaching science. What affects your confidence to teach science?

Your name?

Final Reflections: Administered after the professional development intervention

Final Reflections

To what extent has this professional development experience impacted your practice?

Describe how the professional development has changed your confidence about teaching physical science.

How have the new practices you have implemented impacted your students? How do your students influence your practice?

How could I improve this professional development in the future?

Your name

APPENDIX H

Science Teaching Efficacy Beliefs Instrument (STEBI)

Science Teaching Efficacy Belief Instrument*

Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.

SA = Strongly Agree
A = Agree
UN = Uncertain
D = Disagree
SD = Strongly Disagree

1.	When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	SA A UN D SD
2.	I am continually finding better ways to teach science.	SA A UN D SD
3.	Even when I try very hard, I don't teach science as well as I do most subjects.	SA A UN D SD
4.	When the science grades of students improve, it is most often due to their teacher having found a more effective teaching approach.	SA A UN D SD
5.	I know the steps necessary to teach science concepts effectively.	SA A UN D SD
6.	I am not very effective in monitoring science experiments.	SA A UN D SD
7.	If students are underachieving in science, it is most likely due to ineffective science teaching.	SA A UN D SD
8.	I generally teach science ineffectively.	SA A UN D SD
9.	The inadequacy of a student's science background can be overcome by good teaching.	SA A UN D SD
10.	The low science achievement of some students cannot generally be blamed on their teachers.	SA A UN D SD
11.	When a low achieving child progresses in science, it is usually due to extra attention given by the teacher.	SA A UN D SD
12.	I understand science concepts well enough to be effective in teaching elementary science.	SA A UN D SD
13.	Increased effort in science teaching produces little change in some students' science achievement.	SA A UN D SD
14.	The teacher is generally responsible for the achievement of students in science.	SA A UN D SD
15.	Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	SA A UN D SD
16.	If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher.	SA A UN D SD
17.	I find it difficult to explain to students why science experiments work.	SA A UN D SD
18.	I am typically able to answer students' science questions.	SA A UN D SD
19.	I wonder if I have the necessary skills to teach science.	SA A UN D SD
20.	Effectiveness in science teaching has little influence on the achievement of students with low motivation.	SA A UN D SD
21.	Given a choice, I would not invite the principal to evaluate my science teaching.	SA A UN D SD
22.	When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better.	SA A UN D SD
23.	When teaching science, I usually welcome student questions.	SA A UN D SD
24.	I don't know what to do to turn students on to science.	SA A UN D SD
25.	Even teachers with good science teaching abilities cannot help some kids learn science.	SA A UN D SD

APPENDIX I

Modified Attitudes towards Science Inventory

Survey of Attitudes Towards Science

The following statements are about the study of science. Please listen to, and read, each statement carefully. Use the following scale to show how much you agree or disagree with each statement.

If you STRONGLY DISAGREE	●	(2)	(3)	(4)	(5)	
If you AGREE	(1)	●	(3)	(4)	(5)	
If you are UNDESIDED	(1)	(2)	●	(4)	(5)	
If you AGREE		(1)	(2)	(3)	●	(5)
If you STRONGLY AGREE	(1)	(2)	(3)	(4)	●	

It is important that you respond to *every statement*, and that you fill in only one number per statement.

ATSI ITEM STATEMENTS	SD				SA
1. Science is useful in helping to solve the problems of everyday life.	(1)	(2)	(3)	(4)	(5)
2. Science is something that I enjoy very much.	(1)	(2)	(3)	(4)	(5)
3. I would like to do some extra or un-assigned reading in science.	(1)	(2)	(3)	(4)	(5)
4. Science is easy for me.	(1)	(2)	(3)	(4)	(5)
5. When I hear the word <u>*science*</u>, I have a feeling of dislike.	(1)	(2)	(3)	(4)	(5)

6. Most people should study some science.	(1)	(2)	(3)	(4)	(5)
7. Sometimes I read ahead in our science book.	(1)	(2)	(3)	(4)	(5)
8. Science is helpful in understanding today's world.	(1)	(2)	(3)	(4)	(5)
9. I usually understand what we are talking about in science.	(1)	(2)	(3)	(4)	(5)
10. Science teachers make science interesting.	(1)	(2)	(3)	(4)	(5)
11. No matter how hard I try, I can not understand science.	(1)	(2)	(3)	(4)	(5)
12. I feel tense when someone talks to me about science.	(1)	(2)	(3)	(4)	(5)
13. Science teachers present material in a clear way.	(1)	(2)	(3)	(4)	(5)
14. I often think, "I cannot do this," when a science assignment seems hard.	(1)	(2)	(3)	(4)	(5)
15. Science is of great importance to a country's development.	(1)	(2)	(3)	(4)	(5)
16. It is important to know science in order to get a good job.	(1)	(2)	(3)	(4)	(5)
17. I like the challenge of science assignments.	(1)	(2)	(3)	(4)	(5)
18. It makes me nervous to even think about doing science.	(1)	(2)	(3)	(4)	(5)
19. It scares me to have to take a science class.	(1)	(2)	(3)	(4)	(5)
20. Science teachers are willing to give us individual help.	(1)	(2)	(3)	(4)	(5)
21. It is important to me to understand the work I do in science class.	(1)	(2)	(3)	(4)	(5)
22. I have a good feeling toward science.	(1)	(2)	(3)	(4)	(5)
23. Science is one of my favorite subjects.	(1)	(2)	(3)	(4)	(5)
24. I have a real desire to learn science.	(1)	(2)	(3)	(4)	(5)
25. I do not do very well in science.	(1)	(2)	(3)	(4)	(5)