TRADITIONAL DEFAULT: IDENTIFYING BARRIERS THAT LIMIT REFORM PRACTICE IN BIOLOGY CLASSROOMS

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ABSTRACT

This dissertation is a mixed methods study designed to identify specific characteristics of teachers who successfully implement reform teaching in science classrooms. Barriers of reform practice were also explored among groups of teachers who previously participated in professional development grounded in reform methods. Fifteen participants took part in the study. Data was collected using observation instruments, self-evaluations and interviews to establish a relationship between practice, Pedagogical Content Knowledge (PCK) and beliefs about teaching and learning. A baseline of reform practice was established using the Reform Teaching Observation Protocol (RTOP). The RTOP served as a diagnostic tool identifying differentiated practices among the 15 participants. The Science Teaching Efficacy Belief Instrument for In-service Teachers (STEBI-A), identified teachers' beliefs about student learning. Interview data provided qualitative evidence which supported the findings.

The results of this study identified five of the 15 participants as Active Learning teachers who proficiently implemented reform practices. These teachers shared a belief that their teaching practices impacted student learning. They identified their role in the classroom as a facilitator who promotes student discourse and who also creates an inclusive classroom culture. A major finding of this study is the identification of a skill that this researcher refers to as

Facilitator Pedagogical Knowledge (Facilitator PK). Lack of Facilitator PK was observed as a barrier to reform teaching. The implications of this study suggest that professional development focused on Facilitator PK could increase the success of reform-based practice in science classrooms.

DEDICATION

I dedicate this dissertation to my children, George Chambers and Analise Chambers. I am as proud of you as any parent could be. You might not have known, but your smiles kept me going. A special thank you to my sister, Sherri Findley, my partner, Michael Lee Springfield and the many friends who stepped up with encouraging words during my times of self-doubt.

In memory

I would like to make a special dedication to my mother, Betty Kreon. Your strength and perseverance have been my inspiration. My own achievements cannot compare to the obstacles you rose above. Cottonball, you were excellent company during those late night. You are missed.

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CHAPTER 1
INTRODUCTION

The purpose of this explanatory mixed-methods study was developed to understand the readiness of teachers to enact the pedagogical skills affiliated with reform based instructional practices. This study explored the varying degrees of reform methods that secondary life science teachers enacted in their classrooms and examined the predictors and barriers that influenced reform efforts. This two-phase mixed-methods approach utilized the constructivists' framework, viewing teachers as learners and identifying elements that influence their instructional strategies.

In 2015, the Program for International Student Assessment (PISA) tested 28 million fifteen-year-old students in 72 economies. The PISA test is an evaluation of three knowledge domains: reading, math, and science. In keeping with past scores, the United States of America maintained a standing of barely above average for the Organization for Economic Cooperation and Development (OECD) countries (PISA, 2015). The PISA results identified a concerning trend, that children living in poverty ranked nearly last in all subjects. This data was supported by data from the National Assessment of Educational Progress (NAEP). The results from the NAEP assessment mirrored this trend. The NAEP data indicated that students in states with a higher median of per capita income scored much higher than students living in high poverty states. The scores ranged from 18 points above the national average to 15 points below (NAEP, 2016). In 2015, according to the Bureau of Economic Analysis (BEA), Massachusetts, holding the top score, reported a per capita median income of approximately $8,000 higher than the national average. In comparison, Alabama, scoring at the lowest level, had a median per capita income of approximately $11,000 lower than the national average (BEA, 2017). A 2011 survey by the Department of Education found that 45% of high-poverty schools received less state and local funding than was typical for other schools in their district (U.S. Department of Education, 2011). This data indicated that economic disparity could be a strong factor contributing to educational inequality.

The commonality between the assessment goals of the PISA and NAEP is the focus on addressing how well students can understand and apply knowledge to real-life situations. The assessment of critical thinking skills and problem solving is viewed as an indicator of how well an economy will fare in a changing world. In response to the low performance of U.S. students on national and international assessments, national efforts such as the Howard Hughes Medical Institute (HHMI) and the U.S. Department of Education continue to award grants to systems and states that are instituting educational reform efforts. These efforts are grounded in the *Benchmarks for Science Literacy* (AAAS, 1997, p. 1), a document which outlines the goals of the modern science reform movement. The need for educational reform, particularly in science education, was concisely stated by President Barack Obama, "[Science] is more than a school subject, or the periodic table, or the properties of waves. It is an approach to the world, a critical way to understand and explore and engage with the world, and then have the capacity to change that world…."(Obama, 2015). This quote is a reflection of the language found in the contemporary reform publication, *Science for All Americans* which describes the vision of the modern reform movement as "a unified vision of science literacy that serves as a basis for discussions of the skills and knowledge that our nation's students should have…." (AAAS, 1989, p. xvi).

In 2015, the state of Alabama adopted a new course of study for science which parallels the three dimensions of the Next Generation Science Standards (NGSS, 2013, pp. 40-96). The roots of the NGSS can be traced back to *Benchmarks for Science Literacy* (NGSS, 2013, p. 3). The NGSS narrowed the teaching and learning approach to the application of a conceptual change model or reform teaching model. Conceptual learning is focused on facilitating knowledge of broad principles and ideas that are transferable to novel situations. The Alabama Course of Study for science (ACOS) has adopted the reform approach by incorporating the three dimensions of the NGSS; Cross Cutting Concepts (CCC's) and Science and Engineering Practices (SEP's) that are woven into the Disciplinary Core Ideas (DCI's), (ACOS, 2015, p. iv). These standards require the "knowledge needed to teach" (Schulman 1987), defined as science teachers to have Pedagogical Content Knowledge (PCK) grounded in reform practices in order to improve student learning. Implementing these standards requires a pedagogical shift from teacher centered instruction to student centered learning, which is congruent with the constructivists' framework for reform education. Teacher efficacy may affect the degree to which teachers successfully implement the instructional practices of the science teaching standards. Teacher efficacy is the confidence in one's ability to successfully promote student learning (Hoy, 2000). Positive teacher efficacy has been correlated with student achievement and could influence the practices that he/she deems the most beneficial for student learning (Tschanned-Moran, Woolfolk, Hoy & Hoy, 1998, Ashton & Webb, 1986). The confidence factor may act as a predictor of reform classroom practice.

In addition to the concerns over inequality, as highlighted in the PISA and NAEP scores, there is a growing national trend reflecting a decline in the pursuit of science, technology, engineering and math (STEM) fields. The results of a 2019 survey, conducted by the Junior

Achievement USA group, showed STEM interest decreased by 11% in girls aged 13 to 17 years. Boys' interest increased three percent from the previous year. This survey did not indicate additional demographic markers such as family income or race (https://www.juniorachievement.org). Data collected by the National Science + Math Initiative (NSMI) reported in 2013 that thirty-six percent of high school graduates are prepared for college level science (http://www.nms.org). The NSMI is a non-profit organization that promotes improving the quality of local and state STEM education with the goal of achieving college and career readiness. Recent data reported 11% of the 2018 Alabama high school graduates met the ACT STEM college readiness benchmarks (ACT, 2018). The ACT defines college readiness benchmarks as test scores that indicate a reasonable chance of student success in their first-year credit courses (Allen & Radunzel, 2017). The ACT data could indicate that these students are not proficient in processing information aligned with reform teaching.

The need for in-service and pre-service teachers to move their instruction towards a reform approach is an issue that resonates on a national level (*A Framework for K-12 Science Education*, 2012). In the course of my profession as an ASIM Biology Specialist, this researcher has had the opportunity to observe teachers as they work towards implementing the 2015 ACOS. My observations have indicated that most teachers continue to default to teacher-centered, lecture based, traditional teaching rather than move towards student-centered, inquiry methods that are associated with reform practices. These teachers are attempting to navigate a new realm of reform teaching and conceptual learning without truly understanding how educational reform looks in their classrooms, schools and systems. Teachers may feel that they are ill-equipped to successfully improve student learning through a constructivist process. Educating teachers in reform methods requires professional development for in-service teachers with an emphasis on

PCK aimed at engaging teachers in constructivist practices. This study provided insight into the elements of reform professional development that influence the classroom environment. The following areas of reform teaching were explored: 1) the degree that teachers use reform practices in their classroom, 2) the barriers that influence reform practice, 3) the predictors that influence reform practice, 4) the level of teacher efficacy using reform practices and 5) the relationship between the two constructs of proficient implementation of reform practice and teacher efficacy. The information gained from this research will help guide future investigations into professional development practices for local and national efforts.

Background

Carl Wieman (2007) emphasized scientific training is no longer just for those select few individuals who aspire towards a career in science, but a necessity for achieving a more scientifically literate populace. The emerging economy, as well as global issues will require a populace capable of navigating complex problems that require critical thinking and an understanding of how science works. Wieman described science education as a tool which transforms the science classroom from a passive learning environment into a dynamic experience which facilitates an understanding of how science works. In order to achieve this goal, science teachers will need to redesign their practice in a manner that supports conceptual understanding based on the constructivist's framework. Redesigning classroom practice from a teacher-centered learning environment to student-centered instruction is a major shift for many science teachers. Fostering an academic culture where students engage in the active struggle of finding patterns and relationships among the disciplinary core ideas will require professional development supporting a reform approach. Without the benefit of professional development geared towards guiding teachers to navigate this new approach, instruction will likely remain stagnated in traditional practices. This stagnation will fail to move science education towards the vision described by Wieman (2007).

Emerging research on teacher professional development programs (PDPs) in which science teachers redesign, redefine or enhance their classroom practice cites professional development as an ongoing learning experience that every teacher should pursue throughout their teaching career. This is particularly true for educators in the field of science (Luft and Hewson, 2014). Luft and Hewson described the current focus on science teacher professional development that is relevant to this study. Emerging knowledge in teacher research includes:

- PDPs, curriculum and teachers - how do teachers use curriculum?
- Instructional practices as a result of PDP-s- what elements of professional development using standards-based instruction do teachers incorporate in their practice?
- PDPs and teacher self-efficacy--monitoring the change of science teachers' self-efficacy as promoted by professional development.

These three areas of research are essential considerations as the state of Alabama transitions to a standards-based curriculum which incorporates elements of the NGSS. Professional development will play a central role in guiding teachers towards a student-centered learning environment that supports the conceptual framework of the 2015 ACOS. In addition to the above referenced ACT data, a similar pattern emerged with the findings of the 2015 National Assessment of Educational Progress (NAEP). Twenty-one percent of 8th grade students in the state of Alabama scored at or above the proficient level in science (National Center for Education Statics (NCES) Home Page, a part of the U.S. Department of Education, n.d.). The transition from an objective based science course of study to a conceptually based framework could be the first step towards improving student achievement and proficiency on national assessments.

The 2014-2015 school year was the final year for the 2005 Alabama Course of Study (ACOS) for science. Implementing the new standards and practices on a classroom level will require a pedagogical shift from teacher-centered instruction towards student-centered learning by embracing the theoretical framework of conceptual change.

Conceptual Framework

The major conceptual perspective for this study is grounded in the constructivist's framework. There is a wide array of research that supports constructivism as a best practice of teaching and learning. The core of constructivism approaches learners as actively constructing their own knowledge from experience. Students integrate new knowledge with existing knowledge through inquiry and exploration (Bruner, 1966). Teaching, using constructivist methodology, requires educators to provide complex learning situations that relate to real life experience (*A Framework for K-12 Science Education*, 2012). The constructivist framework for this study provided a lens for examining the degree of impact that professional development has on classroom teachers as they shift their classroom learning from teacher-centered environments to student-centered environments. This framework also supported research-based strategies aimed at deepening teacher pedagogical content knowledge when implementing reform practice.

Theoretical Perspective: Conceptual Change and Teacher Efficacy

Theoretical perspective

The theory of conceptual change is an instructional approach that is found within the framework of constructivism. Conceptual change is learning science from a constructivist's perspective (Duit, 1999). Conceptual change research works within the broad framework of constructivism, however the nuance of the conceptual framework is found in the Piagetian theory of assimilation and accommodation which are pathways for shifting student preconceived ideas towards understanding of a scientific paradigm (Piaget, 1950, 1952, 1971), (Kuhn, 1970), (Duit, 2003). Based on this research, several models of conceptual change instruction have emerged. Most notably is the model of Strike and Posner (2007) which states that student preconceived ideas are derived from personal experience. The four factors required to move student alternative conceptions towards a higher degree of scientific thinking are: 1) dissatisfaction with the existing idea; 2) intelligibility, the new idea must make sense and the learner should be able to explain the concept to his or her peers; 3) plausibility, the new conception should make more sense than the alternate conception; 4) fruitfulness, the new understanding should be applicable to novel situations (Posner, Strike, Hewson & Gertzog, 1982, p. 214).

A reform-based model is published in the 2015 ACOS as best practice for science education. This model is the Bybee 5E Instructional Model. The elements of this model are; Engage, Explore, Explain, Extend/Elaborate, and Evaluate, and are presented as a method of promoting conceptual change (AAAS, 2001; Bybee, 2006; ACOS, 2015; NRC 1996).

Teacher efficacy

Teacher efficacy is defined as the confidence in one's ability to successfully promote student learning (Hoy, 2000). Positive teacher practices are associated with high self-efficacy. Teachers with a high level of self-efficacy exhibit greater levels of planning and organization, they are open to new ideas and are persistent in pursuing strategies that they deem as beneficial to student needs (Jerald, 2007). The willingness of teachers to implement new methods of instruction is the cornerstone for change as teachers move from traditional, teacher-centered environments to conceptual student-centered learning. Badura (1977) states that, "Given appropriate skills and adequate incentives, however, efficacy expectations are a major determinant of people's choice of activities, how much effort they will expend, and how long they will sustain effort in dealing with stressful situations" (p. 194). The belief that one can make a difference in student learning has been correlated with teacher efficacy (Woolfolk, Rosoff, Hoy, 1990). Efficacy beliefs may influence how much effort a teacher is willing to put forth in order to change practices in their classrooms. Self- efficacy may play a critical role as teachers embrace reform practices.

Statement of the Problem

This study addressed the problems and concerns teachers experience as they move from teacher-centered, traditional instruction, to a reform-based approach. The question to be answered is *why do teachers with similar reform-based professional development experience vary, in their degree of reform classroom practice?* A probable cause could be the lack of familiarity with the new approach. Teacher perceived self-efficacy may also play a role in the persistence of classroom teachers to default to traditional methods of teacher-centered, lecture-based pedagogy. As previously discussed, there is data showing the low percentage of Alabama students mastering Science Technology Engineering and Math (STEM) classes. There remains a need for research addressing this data. Observational evidence suggested that teachers rarely utilize the PCK associated with reform practice. This research explored the factors which influence teachers to continue traditional methods in favor of reform teaching, even after participating in reform-based professional development. This study explored the body of knowledge surrounding the choices of pedagogical strategies employed by teachers and how those choices are influenced by predictors of reform practice.

The national significance of this problem is expressed by the NSTA position statement, outlining the need for The Next Generation Science Standards (NGSS) "Science education traditionally has focused on large volumes of content, primarily basic facts and vocabulary, while falling short on the deeper understanding of key scientific concepts and the application of these concepts to daily life" (NSTA, 2017, p. 1). The educational goal of the NGSS is to change the focus of K-12 science education so that all students will have the capability to make informed decisions based on a conceptual understanding of the standards.

The mission of the NGSS was crafted in response to a national movement whose purpose is to improve STEM education (NGSS, 2013, p.3). According to the 2015 National Assessment of Educational Progress (NAEP) scores, approximately 30% of eighth grade U.S. students were proficient in math and science for every grade level, as indicated on the National Center for Education Statistics (NCES) Home Page, a part of the U.S. Department of Education, n.d., Fig. 2). In 2010, President Barack Obama announced a program called Race to the Top. This, four-billion-dollar grant-funded program was designed to transform the culture of teaching and learning for science and math related fields, including technology and engineering. A component of this grant states that a crucial goal is to adopt "standards and assessments that prepare students to succeed in college and the workplace and to compete in the global economy" (U.S. Dept. of Education, 2010). This national vision aligns with the three strands of the NGSS and the College and Career Readiness Standards (CCRS) which are designed to blend content and practice in a method used by scientists and engineers. This approach to teaching and learning is grounded in the reform teaching efforts which support the critical thinking skills that are necessary for students to be successful in STEM related fields.

Achieving classroom reform, both on the national and regional levels will require a systematic effort calling for changes in curriculum and in assessments for students as well as teachers. Professional development for teachers is a cornerstone for successfully transitioning from a teacher-centered environment to a student-centered environment and building teacher efficacy (Min Liu, 2003; Ross & Bruce, 2007).

The SEP's are designed for a student-centered approach in which students actively take control of their learning by supporting ideas, designing experiments, and presenting data in a debate style format that fosters conceptual change (Vosniadou, , Loannides, Dimitrakopoulou, & Papademetriou, 2001). This researcher's classroom observations revealed that many high school science teachers appeared to be unfamiliar with the PCK necessary to structure their classrooms in order to foster a student-centered approach. Teachers also demonstrated a weakness in creating scientific collaborative communities within their walls. This process can be nurtured through pedagogical approaches such as Argument Driven Inquiry (ADI) (Sampson, 2013) strategies. Many of the science standards in the 2015 ACOS include an ADI approach for teaching content. The ADI method closely aligns to the Biological Science Curriculum Study (BSCS) 5E Model of Instruction. This model is the required pedagogical approach cited in the 2015 ACOS. The five phases of this model: engage, explore, explain, elaborate, and evaluate, are designed to facilitate conceptual learning (Bybee, 2015). An in-depth review of this model is outlined in Chapter 2. Although the 5E method is a required strategy for Alabama teachers, only a small portion of these teachers have been observed employing reform methods to fidelity.

Purpose of the Study

The purpose of this study was to identify factors influencing teachers as they attempted to shift their instruction towards student-centered learning. The following elements are included in the scope of this study: A survey of a sample number of biology teachers from the Southeastern region of the United States, who share common professional development experiences using reform methods; the impact of reform-based professional development; the impact of teacher efficacy on reform efforts; and recognizing possible barriers and predictors of reform teaching.

Research Questions

1. To what extent are biology teachers implementing reform based instructional practices in their classrooms?
2. What factors influence biology teachers to abandon reform education strategies and default to traditional methods of teaching?
3. What factors predict whether biology teachers will use reform strategies in the classroom?

Significance of the Study

As of February 2016, 18 states and the District of Columbia have adopted the Next Generation Science Standards (NGSS). Alabama and South Dakota are examples of state science programs that have adopted science standards like the NGSS in content and require modeling of the NGSS three-dimensional learning practices. Alabama, like many states, provides a learning cycle model, such as the 5E model and it is assumed that the teachers can proficiently interpret and execute this model in their classrooms. A survey conducted by the National Academy of Science, indicated that "a significant number of U.S. science teachers hold pedagogical perceptions that are aligned with a conventional view of teaching" (NAS, 2015). This survey indicated that professional development based on a reform model is in high demand. Banilower, Smith, Weiss, Malzahn, Cambell, & Weiss, (2013) reported that 60% of teachers self-assess as using reform methods. However, evidence also suggests that these teachers most frequently engage in traditional teaching and only occasionally implement the elements characteristic of a reform classroom. In view of this dichotomy, it is probable that the shift from traditional teaching to a reform framework encompassing inquiry reform practice will be difficult for most teachers. It is also probable that teachers who rank low on the self-efficacy scale (APPENDIX D) will be less likely to implement many of the elements of reform science teaching.

This research focused on a professional development program for classroom science teachers using a reform-based model. This research gathered evidence identifying the elements of PCK necessary for life science teachers to effectively model reform teaching. Evidence supporting this research included perceived self-efficacy and elements of reform-based classroom culture.

The course of study standards adopted by several states incorporate the practices of the NGSS; Disciplinary Core Ideas (DCI's), Cross Cutting Concepts (CCC's), and the Science and Engineering Practices (SEP's). For many states this means following an inquiry-based format and shifting away from fact-based content. For example, the Alabama Course of Study for Science advocates the 5E model as the preferred method of instruction. This reform model required most teachers to shift their instruction from a teacher-centered classroom to a student-centered environment. As the previous ACOS for science was not based on the 3 Dimensions of the NGSS, it is therefore assumed that many teachers in the state of Alabama, have limited experience using the 5E reform model. Evidence collected from this study could offer suggestions for further research supporting changes in reform-based professional development.

Research Design

The research design of this study employed a mixed methods approach to more fully understand variables affecting reform teaching. Using a mixed methods approach can diminish the limitations by providing a more complete understanding of the research problem than using either approach in isolation (Creswell & Clark, 2011). The research design for this study merged the qualitative and quantitative data by cross integrating evidence strands. This method is the Explanatory Sequential Design (Ivankova, Cresswell, & Stick, 2006).

Fifteen high school Biology teachers who have participated in Alabama Science in Motion (ASIM), reform-based, professional development were selected as participants. This study used a randomly selected sample with the independent variable as the number of days that the teachers participated in reform-based professional development (minimum 10 days post 2014). The sample selection region was in the Southeast part of the United States. Teaching experience ranged from two years to twenty-three years.

Delimitations of the Study

This study was limited to Alabama high school biology teachers who have participated in ASIM professional development focused on the PCK required to effectively teach three-dimensional learning as required by the 2015 ACOS for science. Few studies have been conducted linking in-service teachers' shift toward reform practices and predictors that contribute to the willingness of teachers to restructure their teaching methods. This study will contribute to the body of knowledge regarding effective professional development both at the state and regional level that is designed to move teachers toward reform education.

Definitions

During this study the following operational definitions were used.

- ASIM professional development-professional development centered on conceptual practices that incorporates the three dimensions of the NGSS. ASIM professional development provides lab-based training and content deepening for high school biology, chemistry and physics, using the 5E instructional model. This professional development emphasizes the three dimensions of the NGSS that are woven into every lab and hands-on activity. ASIM professional development is a state sanctioned training program that is a part of a larger reform effort (APPENDIX: I).

- Conceptual Change - Conceptual change is generally defined as learning that changes an existing conception (i.e., belief, idea, or way of thinking).
- 5E Instructional Model -The instructional model is based on constructivist learning theory. This model advocates that students learn best through a variety of learning experiences structured by the teacher. Teachers organize student centered learning into five phases – Engage, Explore, Explain, Elaborate, and Evaluate. The purpose of this instructional model is to move students' preconceptions towards explanations and understanding that are more closely aligned with the scientific paradigm.
- Modeling of the NGSS conceptual practices – The NGSS adopted the conceptual practices from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012). Modeling of these practices entails the presentation of a coherent set of core ideas whose purpose is to provide a common foundation for further investigation. The exploration of these ideas allows students to question, create models, and investigate a phenomenon with the goal of developing an explanation of how or why something happens.
- Next Generation Science Standards (NGSS)- scientific practices that include the critical thinking and communication skills those students need for postsecondary success and citizenship in a world fueled by innovations in science and technology. These practices

encompass the habits and skills that scientists and engineers use day in and day out (NGSS, 2013).

- Pedagogical Content Knowledge (PCK)- a type of knowledge that is unique to teachers and is based on the way teachers relate what they know about teaching to their subject matter.
- Reform Instructional Model- A systematic effort which includes federal education initiatives, state curriculum and policy decisions, system buy-in and teacher support, professional development opportunities, teacher pre-service programs and any other area of education that can influence the deliberate effort to develop critical thinking, collaboration and problem solving skills to all students.
- Teacher Efficacy-Teacher efficacy has been defined as "the extent to which the teacher believes he or she has the capacity to affect student performance" (Berman, et al,. 1977, p. 137). Teacher efficacy exists in two dimensions, general teaching efficacy and personal teaching efficacy. Personal teaching efficacy refers to a teacher's confidence that they will have a positive outcome on student achievement (Hoy, 2000). General teaching efficacy refers to a teacher's confidence that skillful instruction as a collective whole can offset the effects of a disadvantaged home life (Coladarci, 199

CHAPTER 2
REVIEW OF THE LITERATURE

The purpose of this chapter was to provide an in-depth review of the pertinent literature surrounding the issue of instructional practices in science education. The first section is a brief background of the reform framework and a discussion of student achievement considering reform education in science classrooms. The second section offers a closer look at how the 2015 Alabama Course of Study (ACOS) is influenced by the practices of the NGSS that are rooted in the reform effort. Section 3 examines how this approach is related to student achievement. Sections four through seven are more closely related to general question number one and that addressed the teachers' fidelity to reform practices. The fourth section provides a deeper look at the relationship between teacher efficacy and pedagogical content knowledge impacting the reform model. The fifth section examines the role of teacher efficacy and the impact on student achievement. The sixth section looks at professional development in reform practices and the impact of these programs in science classrooms. The seventh section links professional development in reform practices to the context of student achievement. The final section discusses the instruments specific to this study that are used to measure reform teaching and teacher efficacy.

The Reform Instructional Model and Student Achievement

The 2015 ACOS is an outcome of a larger national reform initiative spurred by the publication of *A Nation at Risk*, 1983, a study conducted by the National Commission on

Excellence in Education. The results of this study concluded that U.S. students were falling behind in math, science, and technology education. This study stoked the fear that U.S. students would be ill equipped to compete in a world economy. The response gave rise to the National Science Education Standards (NSES, NRC, 1996). The NSES provided a vision for science education reform. These reform standards provided a framework for vertically aligned goals spanning K-12 science education (Park, 2006). This new way of teaching advocated employing pedagogical strategies that aligned with the reform model and emphasized shifting from teacher-centered to student-centered environments. This general reform framework is the foundation for several programs that are currently influencing curriculum with the goal of improving science education. One of these programs centered on the reform effort is Science, Technology, Engineering and Math (STEM) education. The following is a meta-analysis of STEM directed educational programs.

In recent years, programs that promote the STEM approach have become a prominent component of reform education. The protocol of STEM education includes the following characteristics: shifting traditional lecture-based teaching to an inquiry approach, integrating science, technology, and math subject matter as well as modeling the three dimensions of the NGSS and modeling how science works in the real world (Breiner, Harkness, Johnson & Koehler, 2012, p. 4). Although the body of research on STEM teaching and student achievement remains scant, Becker and Park (2011) compiled and executed a meta-analysis on a collection of 28 studies dealing with this topic. Their research choices were influenced by three criteria: 1) The research was published between 1989 and 2009. 2) They were searched using the ERIC database, Digital Dissertation and Google Scholar for the key words "integrative curriculum", "integrated curriculum, "integration", "science and technology education", "science and mathematics education" etc. 3) They examined student achievement for quantitative results. The participants ranged from a minimum of 21 students to a maximum of 1,053 students. After combining the 28 studies based on the above criteria, Becker and Park examined the effect size for grade bands. The results showed an increase in effect size over elementary school, middle school, high school, and undergraduate college students enrolled in STEM classes. The most significant effect occurred in elementary schooling. The results of this data are limited because 28 studies are a small number for a meta-analysis and each study collected data using a different methodology. However, the data indicated the STEM approach, particularly at early ages, may be tied to higher achievement. The implications of this data are related to this current study in that they highlight a need for educators to become proficient facilitators of the integrated approach as advocated by the NGSS and the 2015 ACOS for science.

A second study by Ruiz-Primo, Shavelson, Hamilton, & Klein, (2002) is included due to its direct relationship to reform education as outlined by the National Science Foundation (NSF). The NSF defines reform as, "moving from a focus on textbooks and disconnected facts toward direct and coherent exploration of science concepts through active student learning" (Cozzens, 1997, p. vii). This reform study employed a method which is described as a multilevel-multifaceted approach. Multilevel analyzed student achievement based on close parallel with content and experiences, proximal assessments analyzed the skills that are relevant to the topics of instruction and distal analysis reflected the disciplinary core ideas found in national standards. Multifaceted referred to the employment of different types of tests designed to identify the different facets of knowledge. The authors stated that the multifaceted assessment reflected a broader sense of achievement as outlined in conceptual models of applying knowledge to solve problems. The multilevel-multifaceted approach was designed to examine student achievement along with the nuances that can influence student achievement. It was the belief of the researchers that educational reform often fails because policy makers are looking for big gains rather than nurturing the factors that show small improvements.

The Ruiz-Primo (2002) study began with the implementation of a reform-based science curriculum known as the Full Option Science System (FOSS) modules. These FOSS modules were structured and scaffolded to align with the NGSS standards. They included a teacher guide, hands-on resources for exploration activities, and an instructor training video. It is unclear if the participating teachers received additional instruction prior to the study. The participants included twenty fifth-grade classrooms for a total of 481 students. Students engaged in science notebook exercises as they proceeded through two of the FOSS modules. The notebooks were evaluated for communication skills and conceptual understanding related to the multifaceted portion of the study. Pre-test and post-test data were analyzed for multilevel knowledge and students were randomly assigned proximity to the topic. The data was collected and analyzed based on the following guiding questions: Did the students' science notebooks capture any effect of instruction on students' learning? Did the instruction impact student performance? If such an impact was detected, did its estimated magnitude depend on whether a close or proximal assessment was used?

Evaluation of the notebooks revealed students had poor communication skills and only a partial grasp of the concepts surrounding the phenomenon of mixtures and solutions. The researchers concluded that the FOSS module instruction had an impact on students' performance. Significant differences were observed between pre-test and post-test data. The performance assessments and notebooks were also coded to test the procedural, strategic and declarative knowledge. However, analysis of the multifaceted part of this study was not included in the results. As predicted, the impact of assessment was more sensitive to closeness of instruction, followed by proximal, and finally, a small increase in distal. The researchers correlated the level of implementation per classroom with an increase in the mean post-test score, indicating that fidelity to the FOSS module improved student learning. Most of the gains were associated with the closeness (content) and proximal (skills and concepts) level.

This limitation of this study is that observational evidence of classroom instruction verifying implementation of the FOSS modules was not reported. The difference between classes was attributed to notebook entries as an indicator of the thoroughness of instruction however, only small samples of randomly selected notebooks were analyzed. Although the research indicated a relationship between thorough implementation of the FOSS kits and student achievement, there was no background information regarding the level of professional development for teachers in areas of reform teaching. Reform practices are the driving force behind the 2015 ACOS, and more specifically, the practices that are the framework of the NGSS.

The Influence of Reform Instruction on the NGSS and the 2015 ACOS

This section examines how the 2015 ACOS is influenced by the reform instructional model of education.

The forward of the 2015 ACOS describes science learning as, "The science standards reflect the interconnectedness of the nature of science as experienced in the real world" (Bice, 2015, p. ii). This approach represents a deeper focus on science understanding that builds across grade bands, increasing the application of rigor at each stage. The structure and philosophy of the 2015 ACOS for life science closely mirrors that of the NGSS. Bybee (2014) described the NGSS as the integration of rigorous content. He further stated that the application of this content is reflective of how science is practiced. The NGSS combines deeper learning experiences of core ideas in science with an understanding of the practices of scientists. The changes that teachers are expected to implement in their classrooms are outlined in the following Science and Engineering Practices (SEPs) of the NGSS:

- asking questions and defining problems
- developing and using models
- planning and carrying out investigations
- analyzing and interpreting data
- using mathematical and computational thinking
- constructing explanations and designing solutions
- engaging in argument from evidence
- obtaining evaluating and communicating information (2013, p. 48).

This reform framework is a common thread in both the 2015 ACOS and the practices of the NGSS. The following paragraph describes Alabama's science education shift from traditional objectives to standards that are reflective of the practices of the NGSS.

The 2016-2017 school year was the first year for science teachers in Alabama to teach using the new course of study. The previous 2005 ACOS for science described the theoretical foundation as a "hands-on", "minds-on" approach to learning with an emphasis on inquiry techniques and science literacy (Alabama Course of Study, 2005). The task force for the 2005 ACOS listed the resource documents as: The Science Bulletin 2001, National Science Education Standards (NSES), Project 2061 Science for All Americans and the Benchmarks for Science Literacy. These documents support teaching for conceptual change; however, the objectives crafted by the task force did not reflect a conceptual change framework. The document more closely resembled pre-reform or traditional curriculum. As an example of the differences in practice, the following compares excerpts from the two versions of the ACOS:

- Identify density-dependent and density-independent limiting factors that affect populations in an ecosystem. Examples: density-dependent-disease, predator-prey relationships, availability of food and water; density-independent-natural disasters and climate. Discriminate among symbiotic relationships, including mutualism, commensalism and parasitism (Alabama Course of Study, 2005, p. 42).

The 2015 ACOS has adopted a set of standards that is more closely aligned with the NGSS and characteristics of a reform instructional instrument. The following excerpt from the 2015 ACOS addresses the same content as the above objective from the 2005 ACOS from the standpoint of three-dimensional learning.

- Develop and use models to describe the cycling of matter (e.g. carbon, nitrogen, water) and flow of energy (e.g. food chains, food webs, bio pyramids, ten percent law) between abiotic and biotic factors in ecosystems.
- Construct an explanation and design a real-world solution to address changing conditions and ecological succession caused by density-dependent and/or density-independent factors (Alabama Course of Study, 2015, p. 47).

When comparing the two passages, the most recent ACOS standard incorporates practices influenced by the NGSS and reflective of reform instruction as indicated by the inclusion of Science and Engineering Practices (SEP's) and the Crosscutting Concepts (CCC's). The SEP's in the above standards require students to develop and use models as well as construct an explanation and design a real-world solution. The CCC's are energy and matter, cause and effect, and stability and change. In contrast, the ACOS 2005 objective reflected traditional learning and is not directly tied to any type of conceptual approach.

The most recent educational model adopted by the state of Alabama is designed to meet the standards of the 5E Instructional Model (Bybee, Taylor, Gardner, Cotter & Powell, 2006). The 5E's are; engage, explore, explain, elaborate, and evaluate. This instructional model is modified to include intervention or acceleration (ACOS, 2014, p. 5). These standards also require teachers to embed the three strands of the NGSS; disciplinary core ideas (DCI's), science and engineering practices (SEP's), and cross cutting concepts (CCCs) into their instruction. These three strands are the basis for the conceptual framework (Next Generation Science Standards, 2013).

The 2016 ACT Aspire scores in science reported that 23% of Alabama 10th grade students who took the test in 2015 met the benchmark standards (Public Affairs Research Council of Alabama, 2016). Benchmarks represent the minimum college readiness score. The development of the ACT assessment is influenced by the NGSS but does not specifically test every standard; rather, the assessments are constructed to measure the ability of students to recognize evidence supporting a claim and apply this knowledge in a more advanced context. The questions are framed around data representation, research summaries and conflicting viewpoints (Preparing for the ACT Test, 2016). This cognitive assessment reflects the three strands of the NGSS. The below average test scores highlighted the need for Alabama to move their students forward in developing critical thinking skills. The need to improve Alabama student achievement on conceptually based assessments influenced the focus on teaching the 5E model for conceptual change.

What is the conceptual change model? The roots of conceptual change are often traced to the constructivist philosophy of John Dewey. Dewey's *Democracy and Education* (1916), asserted that learning is an active process; students must participate in challenging, real life tasks for true learning to occur. Dewey was a pivotal figure in early reform efforts and his philosophy is echoed in modern reform models. Jean Piaget enhanced this framework in his Theory of Cognitive Development. Piaget ascertained that 1) children construct their own knowledge, 2) children learn on their own, and 3) children are motivated to learn. Piaget described knowledge as a reorganization process influenced by environmental experience. The aspect of *assimilation*, using an existing schema to deal with a new situation and *accommodation,* when an existing schema does not work and requires revision, is at the heart of conceptual change (Wood, Smith and Grossniklaus, 2001).

Thomas Kuhn in, *The Structure of Scientific Revolutions* (1970) refined Piaget's theory by identifying a "crisis" as the conflict between a student's initial thinking with an observed scientific phenomenon. The student must adjust and assimilate the new information. By identifying the crisis and effectively structuring the environmental experience, which is reinforced through peer socialization, the student can more closely align his or her thinking with an existing scientific paradigm.

A more contemporary view of modern reform is offered by Posner, Strike, Hewson, & Gertzog, (1982). Posner identified traits necessary for students to accept alternative conceptions which are more closely aligned with scientific phenomenon. Posner postulated these traits as:

- dissatisfaction with an existing concept
- a new conception that is intelligible
- The new conception must appear to be plausible.

- The new conception should suggest the possibility of a fruitful program (Posner, et al., 1982).

Duschel, (1990) compared traditional methods of teaching to constructivists methods by describing the two faces of science: science as a process of justifying knowledge or what we know, and science as a process of discovering knowledge or how we know. The first face has been notated as traditional teaching. Justifying knowledge fails to address the second face of how we have come to discover what we understand about the world (DeBoer, 1991). The movement towards teaching for conceptual change has given rise to several models. The following identifies a few of the leaders in the field of conceptual change that have proposed models for teaching science: Posner (1982), Driver and Erickson (1986), Hewson, (1992), Bybee (1997), Keeley, (2008), The Common Knowledge Construction Model (CKCM), (Ebeneezer, 2009).

The structure of each model is similar in framework as that they incorporate, "a strategy and sequence which involves *experience, interpretation, and elaboration"* (Sunal, 2004, p. 93). Different forms of the cognitive teaching model have been aligned with student achievement. The research included in this literature review is conducted under the broad framework of constructivism and more specifically, conceptual change associated with reform education. These topics are organized into four categories: conceptual change and student achievement, PCK and teacher efficacy, teacher efficacy and student achievement, professional development and teacher efficacy. Although student achievement is not analyzed in this research, all efforts to understand the elements that support conceptual change are examined considering student achievement. The following section is a brief review of cognitive change research as it applies to student achievement.

Conceptual Change and Student Achievement

The publication *How People Learn (*National Research Council, 2000*)*, identified advances in neuroscience which support teaching styles grounded in a conceptual strategy. Biological evidence using brain imaging has revealed that connecting new information with experience and applying that knowledge to a novel situation stimulates neuron activity, creating new and important pathways in the brain. Biological evidence combined with educational research on student achievement using a conceptual approach builds a strong foundation supporting reform practices. The following examines four studies exploring student achievement considering conceptual change methodology.

One of the pivotal studies is an early work by a leader in teaching for conceptual change, George Posner (1982). Posner explored two questions; 1) What conditions allow for one central concept to be replaced by another? 2) What are the features of conceptual ecology which governs the selection of new concepts? Conceptual Ecology is defined as a group of interconnected concepts of schemas (Strike & Posner, 1985, p. 62). Working with college physics students on the topic of special relativity, Posner conducted a series of interviews at different stages of learning which illuminated inconsistencies in the students thinking about science theory. From this work Posner identified traits, like Kuhn's (1970) classical approach, consistent with accepting alternative conceptions.

- dissatisfaction with an existing concept
- a new conception that is intelligible
- The new conception must appear to be plausible.
- The new conception should suggest the possibility of a fruitful program.

From this research and subsequent studies, Posner developed the Conceptual Change Model

(CCM).

- Commit to an outcome.
- Expose beliefs.
- Confront beliefs.
- Accommodate the concept.
- Extend the concept.
- Go beyond (Keeley, 2008).

A similar approach in exploring the effectiveness of conceptual change was regarding CiL and CEPNi, (2012). This mixed methods approach used measures of open-ended questionnaires along with semi-structured student interviews coded for qualitative data. The framework of this study compared three teaching models; the Conceptual Change Text (CCT), which was based on identifying misconceptions through reading, visual models and diagrams; the Reflective Explicit approach, which advocated learning science through activities and discussion; and the Department of Ministry course textbook which used a traditional textbook and lecture approach.

Turkish elementary students were taught material from the Light unit. A content test, certified for reliability, is the instrument used to quantitatively measure student achievement. The study does not indicate if the questions on the content test are objective based or require a conceptual framework to fully address the material. The quantitative results indicated that there is a statistical significantly higher level of student conceptual change using the CCT method. The Reflective Explicit approach also showed evidence of conceptual change. However, the traditional textbook approach showed no evidence of this phenomenon. This publication did not discuss the coding for conceptual change which may have been derived from student interviews.

A third research design used the Common Knowledge Construction Model (CKCM), which is grounded on the framework of the conceptual change model but added a phenomenological component (Ebeneezer et al., 2009). This model employed conceptual change techniques while also exploring the issues that surrounded student achievement. Using a mixed methods approach, seventh grade students in India were taught a unit on excretion using the CKCM. The control group received the traditional lecture approach on the same material. Quantitative analysis, based on a post-test control group, compared the scores from the Excretion Unit Achievement Test. The scores indicated a statistically significant increase in student achievement using the CKCM approach. Qualitative analysis of the same group showed a movement in conceptual change as evidenced by the addition and deletion of ideas from pre-teaching to post-teaching. The conceptual change of this group is also evidenced by the replacement of everyday language with descriptive science terminology. These studies support the goal of the 2015 Alabama Course of Study (ACOS) for science as teachers begin to shift towards conceptually based pedagogical strategies grounded in reform teaching. The following study directly addresses the 5E model of science education that is explicit in the 2015 ACOS.

The 2015 Alabama Course of Study (ACOS) states that teachers follow a modified version of the 5E Instructional Model (Bybee et al, 2006). A 2011 study by Acisli, Yalcin, and Turgut, explored the effectiveness of the 5E Instructional Model (Engagement, Exploration, Explanation, Elaboration and Evaluation) on student achievement. The subjects in this case consisted of 60 first year, undergraduate, general physics students. Thirty of the students were instructed using the 5E Instructional Model while the thirty participants in the control group received a traditional lecture. This quantitative study compared the pre-test and post-test data using a t-test format. The pre-test was completed at the beginning of the semester and the post-test was administered after 7 weeks of instruction. The pre-test scores were closely aligned in both groups however the post-test data showed a significant difference in favor of the experimental group. The researchers concluded that the 5E model is more successful than traditional methods of teaching. The researchers also concluded that the difference in scores were meaningful enough to recommend that all pre-service teachers receive training in 5E instruction (Acisli, Yalcin and Turgut, 2011).

The body of research supporting the effectiveness of teaching for conceptual change and the positive results for student achievement in the science classrooms is growing. However, the purpose of this study was not to add to the body of research exploring student achievement and conceptual change instruction, but to explore the elements of PCK grounded in reform methods that are transferred to the classroom. As teachers share a common experience in reform based professional development, what elements of this experience are they modeling in their classrooms and to what extent? Is teacher efficacy a factor in reform teaching? What elements of PCK are contributing to student-centered learning? Before a student can benefit from student-centered learning, the instructor must be a qualified and confident instrument of conceptual change pedagogy grounded in reform efforts. Without teachers proficient in reform-based models, federal and state academic test scores for science may continue to languish. Building on this idea, the following paragraphs of this literature review are designed to connect how teacher efficacy can influence pedagogical content knowledge, and as a result, strengthen reform efforts.

Pedagogical Content Knowledge (PCK) and Teacher Efficacy

Pedagogical Content Knowledge (PCK) is defined as, "that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (Shulman, 1987, p. 8). Teaching is more than knowing the content, it involves taking that specific, internal body of knowledge and transferring that knowledge in a meaningful way that is accessible to students and generates understanding. The tie to teacher self-efficacy and PCK is supported by the research of Park & Oliver, (2008). Park enacted a case study involving three experienced chemistry teachers with the goal of conceptualizing PCK and identifying the components that constitute PCK. Further analysis explored how these components interacted to form PCK. Several lessons were videotaped and analyzed using the following instruments:

- constant comparative method –identify patterns
- enumerative approach – tally occurrences of previously categorized events
- in depth analysis of explicit PCK

Before and after interviews along with written reflections were conducted as a method of clarification. Of the five explicit features of PCK identified by the researchers, the one relevant to this study is summed up in the supporting statement, “Teacher efficacy was evident as an affective affiliate of PCK” (Park, & Oliver, 2008, p. 268). According to this study, the correlation between teacher efficacy and PCK revealed a “best fit” scenario.

As previously discussed in the introduction, 36% of Alabama students met or exceeded the CCRS benchmarks. Therefore, professional development initiatives will be analyzed in light of the potential impact on increased student achievement. Understanding the factors that influence teacher efficacy as it relates to reform educational practices, may help educators move towards improved student outcomes. The following studies supported the correlation between teacher efficacy and student achievement.

Teacher Efficacy and Student Achievement

Bandura (1994), defines perceived self-efficacy as, "people's beliefs about their capabilities to produce effects" (p. 2). Bandura stated that people with a high degree of perceived self-efficacy were able to visualize success and face difficult situations as well as navigate demanding tasks with less stress. In addition, those with a perceived high efficacy set challenging goals, exhibited analytical thinking and were more accomplished in their performance. Bandura specifically addressed teacher self-efficacy. Teachers who have a high perceived sense of self-efficacy were able to motivate students and create a learning environment conducive towards developing cognitive skills. In turn, Bandura stated that the structure of the classroom will aid in the development of a higher degree of self-efficacy in students. Based on the research by Bandura (1997), it is assumed that teacher self-efficacy will likely diminish if teachers perceive themselves as ineffective facilitators of conceptual change instruction and will likely abandon further reform efforts.

There are limited studies supporting the research that a teacher with a high degree of self-efficacy will have higher student outcomes. Although there is not a comprehensive battery of studies supporting perceived teacher-efficacy and student achievement, the following literature reviews represent the few studies that do support this relationship. The first review is a quantitative study which consisted of 80 Iranian teachers and 150 students. The researchers measured teacher self-efficacy using a questionnaire examining teachers' ideas about their own effectiveness. Students also participated by completing questionnaires about motivation. The research questions were designed to examine the relationship between teacher self-efficacy and student motivation. A second analysis compared teacher self-efficacy and student academic achievement. The results were analyzed using the SPSS software, a one-way ANOVA analysis.

The results indicated a significant positive correlation between teacher self-efficacy and student motivation. Also, the researchers concluded that there is a positive correlation between teacher self-efficacy and academic achievement. In both cases the data indicated that the higher the teachers perceived self-efficacy, the more motivated the students were, and subsequently, these students achieved at a higher academic level (Mojavezi & Tamiz, 2012).

A second study investigated the relationship between several aspects of student outcomes and teacher self-efficacy (Hu, Wang & Chen, 2012). This Taiwanese study selected a group of vocational high school students and teachers. A total of 372 surveys were distributed to the students and then samples of the surveys were randomly selected for analysis. Five hypotheses were proposed investigating different aspects of teacher efficacy, student satisfaction, teaching process and student learning outcomes. The hypothesis relevant to this study stated, "Teacher self-efficacy positively affects student learning outcomes" (p. 79) which is the second hypothesis identified in the study, (H2). The factors were analyzed using the LISREL 8.70 measurement model. The analysis supported H2 stating that teacher efficacy significantly and positively affected learning outcomes. Although both studies support that high teacher efficacy is related to higher academic achievement in students, the studies only focused on the teachers own teaching process and pre-existing PCK. Both studies share a limitation. The results did not examine Personal Science Teaching Efficacy (PSTE) or Student Outcome Expectancy (STOE).

As previously cited, most teachers continue to teach using objective based, teacher centered classrooms (NAP, 2015).   Teachers may question the effectiveness of using a reform-based model even after reform-based professional development. The review of the following studies examines the outcomes of professional development programs designed to target those teacher qualities which best support effective implementation of reform practices.

Professional Development and the Reform Science Classroom

As classrooms continue to move towards implementing reform practices, teacher professional development advocating a student-centered approach will also need to occur. This is not the first time that the U.S. has advocated science education reform. In the past, large scale reform has failed because of lack of attention to school culture, understanding the capacity for change, failure to provide resources necessary for sustainability and sporadic implementation of innovative programs (Wojnowski & Pea, 2014). Stigler and Hiebert (2007) described teaching as a cultural activity that is resistant to change. Implementation of reform practices is a major policy shift for many educational regions that will require change on every level of the educational system. Changes will need to occur in the classroom culture, district policy, university pre-service education and in-service professional development (Fullen, 2016). Fullen refers to the shift of new values and practices as *reculturing.*

A component of this study examines how professional development affects in-service teachers perceived self-efficacy as they shift from teacher centered environments to student centered environments. This shift is in response to a course of study that utilizes NGSS practices, *Designing Professional Development for Teachers of Science and Math* (Loucks-Horsley et al, 2010). Loucks-Horsley, lists the 5 domains that can move teachers from awareness to implementation and sustainability of the new practice:

- learners and learning
- teachers and teaching, how do teachers develop their specialized knowledge and skills and what type of PCK should they be learning

- Nature of Science (NOS), how can the professional development model provide a true nature of science experience and how can this experience by transferred to the classroom
- What is known about adult learning and professional development.
- The Change Process; professional development is a process where teachers transform knowledge and apply new ideas to changes in practice.

The emphasis on professional development grounded in the five domains is key to reform for in-service teachers, "….it is difficult, if not impossible to teach in ways which one has not learned…." (Loucks-Horsley et al, 2010, p. 31).

Models and Approaches to STEM Professional Development (Wojnowski and Pea, 2014) rephrases the challenge of shifting pedagogical strategies from teacher-centered instruction to student-centered learning by reminding the reader that promoting constructivists classroom practices cannot be achieved unless the professional development experience is, itself, a constructivists format. Wojonski and Pea compare the history of professional development programs that have met the professional development goals through external evaluation. Some of these programs are described as follows:

- Improving Science Across Oklahoma (2005) - an initiative designed to train trained teachers using FOSS inquiry science kits and understanding the inquiry learning practices.
- iQuest Professional Development Mode (2007-2013) – a program designed to increase teacher confidence.
- The Boston Science Initiative (2001-2008) – this initiative's goal was to build a diverse capacity of teacher leaders.

The common thread that ties these programs together are shared values, a common vision, and leadership. There is also a strong component of collaboration between teacher, learning and classroom application. The thread that directly relates to this study is that success cannot be obtained without professional and personal efficacy and commitment.

The two broad purposes of staff development are to better understand professional development in order to improve and to strengthen programs and to determine if the professional development was effective in terms of the intended purpose. Guskey (2016) stated that, "Notable improvements in education almost never take place in the absence of professional development…."   (p. 4). Guskey also noted three types of participant learning to be assessed; cognitive, psychomotor and affective. Cognitive learning is centered on pedagogical content knowledge and content understanding. Do the participants have the knowledge of how students learn and understand? Psychomotor goals examine the practices that participants gain as a result of professional development. For example, Do teachers facilitate more student dialog as a result of their experience? The affective goals examine teachers' attitudes, beliefs or dispositions.   Is there a change in teacher efficacy? Do teachers believe that they can influence student learning?

Beaudoin et al, 2013 explored a workshop aimed at improving teacher quality considering the anticipated adoption of the NGSS as the new state standards in biology and the adoption of the Common Core Standards for geometry. This study centered on PCK and the types of learning needed to achieve the conceptual shift necessary for implementation of the new standards. Participants included 74 teachers who volunteered or were recruited by district leadership. Teachers participated in a weeklong workshop focusing on the following eight elements:

- new standards and end of course exams

- educational philosophy as an overarching guide to all instruction
- model lesson presentation
- integrated content lesson presentations
- assessment of student outcomes that meets teacher evaluation expectations
- types of learning including difference in conceptual and procedural learning
- instructional technology
- collaborative lesson development and delivery

Based on a Likert scale the teachers reported perceived satisfaction in all eight areas. The teachers ranked the aspects of collaboration with colleagues to create lesson plans and creation of collaborative student groups as the most beneficial.

This study addressed the need for professional development considering an adoption of new conceptually based standards. According to the survey teachers were aware of the necessary shift to student-centered learning in order to comply with the NGSS and Common Core dimensions. However, there is no evidence that teacher self-efficacy had changed as a result of this professional development. There is no evidence that this endeavor influenced classroom practices or student achievement.

Chval et al, (2008) conducted professional development research framed by the following questions:

- How do science and mathematics teachers perceive their PD experience?
- What do they perceive as their PD needs?
- What are their expectations for effective PD?
- What constrains them from participating in PD?
- How do the experiences, needs, expectations or constraints differ for science?

This survey was completed and returned by 241 middle and high school science and math teachers. The survey consisted of 10 Likert styled questions and open-ended response items. The results indicated that the elements of PCK which would influence the classroom environment were dependent on workshops that addressed their specific content areas. They would like to receive training on strategies that they can "use tomorrow". The survey also indicated that it was important to the teachers that their training was aligned with their state standards. This study did not indicate if the teachers reported professional development needs were executed, nor did it address the impact of professional development on teacher efficacy as they navigated the new standards.

A 2009 study by Kuchey examined the Initiative for Catholic Schools (ICS) and evaluated five outcomes of professional development:

- the participants' reactions
- the participants' learning
- organizational support and change
- the participants' use of knowledge
- skills and student learning outcomes (Kuchey 2009).

The school teams were composed of one or more science instructors, one or more math instructors and the principal; 21 schools participated in the study. The program spanned two years. After attrition, the total number of participants was 18 science teachers with an average of nine years of teaching experience and 22 math teachers with an average of 13 years teaching experience. The group met by discipline and attended a five-day workshop for two summers. The topics of the workshop included constructivist learning theory, the learning cycle, national and state standards, and PCK associated with inquiry-based teaching, curriculum planning and use of technology. In addition to pre-test and post-tests measurements for content knowledge, lesson plans were analyzed, and teachers were observed in their classrooms. Teachers were also administered a content based self-efficacy instrument, Science Teaching Efficacy Beliefs Instrument (STEBI). The results showed a significant increase in self-efficacy for the teachers who participated in the ICS program. In addition, the increase revealed a strong effect. Lesson plans were analyzed, based on constructivist learning theory, intermittently throughout the program. The analysis revealed a marked increase in the application of inquiry pedagogy. Science students in the ICS classrooms demonstrated significant gains in student achievement after the second year. The self-reported limitations of the study point to the selection process of the participants (volunteer basis) and the relatively small sample size that can skew the quantitative results. An additional limitation is the absence of a control group. There is a gap of research that remains as this study did not address the self-efficacy as teachers shift their practices from-teacher centered to student-centered classrooms, nor does it address the elements of the professional development that influence PCK in the classroom.

A 2009 case study by Kazempour looked at classroom teacher changes in core conceptions as a result of professional development. The three core conceptions found to influence instruction were; 1) teacher-guided inquiry and few instructional changes, 2) real world inquiry-based units and reflective teaching, and 3) controlled inquiry and cautious change. The study followed a single teacher who attended the same professional development program for two years. The aim of this study was to find evidence of changes in core conceptions and instructional practice. What are the factors that aid or inhibit inquiry-based teaching? A portion of this study was funded by the Howard Hughes Medical Institute grant used for professional development of high school teachers and science education faculty. The professional development consisted of a two-week summer workshop and three follow-up workshops during an academic school year. The first week consisted of teachers developing inquiry lesson plans on topics that were difficult for students to comprehend. The second week, the participants presented their inquiry lesson to their group peers. A discussion about ideas and ways to improve the lesson provided a reflective groundwork for the teachers. Afternoon sessions allowed teachers to work alongside university faculty conducting authentic research in STEM areas. A qualitative study of a single teacher was deemed appropriate as the goal was to provide a rich, salient description of the factors that influenced change of the teacher's conception and pedagogy. The teacher, who is the subject of the study, had been an educator for 17 years and, at the time of this study, was teaching College Preparatory Biology, Life Science and Advanced Environmental Science. The subject was interviewed, and themes were identified under the auspice of four core conceptions and factors that influence the implementation of inquiry-based pedagogy. This case study concluded that professional development experience should: occur over an extended period of time, involve active participation of teachers by immersing them in authentic scientific inquiry, provide inquiry based activities as well as discussion, model effective inquiry instruction, and allow teachers opportunities for continuous reflections (Kazempour, 2009). The author of this study noted an important detail that the subject of the study did not trust that lower achieving students would benefit from conceptual change pedagogy. These students continued to receive traditional direct instruction. This case study is part of a larger study and is included in this literature review for the purpose of exploring the elements of professional development that influence the PCK of the classroom environment. The gap of this study is in line with previous studies in that it does not address teacher perceived self-efficacy as they shift pedagogical strategy from traditional direct instruction to a conceptual format.

A 2010 study by Anil Banerjee was selected for review as some aspects of this research parallel the goals of this study. Banerjee described a program that involved 10 chemistry and physical science teachers who participated in the Learn-Teach-Assess Inquiry professional development model. The program was designed to help teachers understand inquiry and use inquiry pedagogical methods in their classroom as envisioned by the *National Science Education Standards* (NSES), and as established by the *National Research Council* (NRC), 1996. The goals of this study aligned with the vision of *Inquiry and the National Science Education Standards* (NRC, 2000) which are to educate teachers in the inquiry strategies of:

- engaging their students to ask scientifically oriented questions
- gathering evidence to develop explanations which address their scientifically oriented questions
- formulating explanations based on the evidence
- evaluating their explanation in light of a competing explanation
- communicating and justifying their proposed explanation

The strategies listed above are at the core of moving classrooms towards a conceptual model. For the teachers in this study, implementing these strategies requires a shift in pedagogical strategies akin to the shift in strategies as required for the teachers of the proposed study.

The teachers in this study attended a 40-hour summer workshop over the course of ten days. They also meet during the academic year for two hours per week for ten weeks. This initiative was a three-year commitment. The first year of the study was designed to develop the ability of teachers to write inquiry labs. In the second year of professional development teachers field tested the labs and wrote lesson plans. Field testing feedback was used to modify labs and lesson plans. During year three, the teachers used inquiry labs as the main pedagogical strategy in their classrooms. This part of the study examined teacher PD in inquiry techniques and compared student content knowledge, ability to understand inquiry, and the ability of students to engage in inquiry techniques. The instruments used to collect data included a 15-item test that measured the ability to understand and engage in inquiry. The test was administered in a pre-test and post-test fashion. Classroom observation assessed the degree of implementation of guided inquiry and teacher reflection journals. The results concluded that in order for teachers to lead meaningful inquiry activities, they require adequate subject knowledge, however, inquiry requires more than content alone. Teachers must develop the pedagogical understanding of inquiry before they can engage their students in this process. The study pointed to the fact that teachers have difficulty shifting to inquiry strategies. The gap remains that teacher perceived efficacy was not explored during this study, nor did it address the elements of PCK from the professional development that influenced their classroom practice.

With MSP funding, the state of Indiana launched the Indiana Science Initiative (ISI) program. This study is significant as it relates to teacher efficacy and professional development for science, engineering and math practices. Like the Alabama College and Career Readiness standards, the ISI is also advocating effective teaching of STEM disciplines. During the 2014-2015 academic year, six elementary schools, three intermediate schools and one high school participated in a summer professional development program. Fifty teachers completed the Personal Math Teaching Efficacy (PMTE) test and the Mathematics Teaching Outcome Expectancy (MTOE) test as well as a self-reported assessment of teacher efficacy as it relates to teaching engineering and design practices. The initial results of these tests indicated that teachers need to be better informed about the engineering design process. The professional development program based its design on the pre-assessments mentioned above. The professional development design had three major goals: develop the teacher's conceptual understanding of mathematics and the engineering design process, align the science, math and engineering instruction at the classroom level, and develop mathematics extensions from science and engineering modules as applications of the science content. The ensuing professional development design used the foundational theory for the engineering design process as described in the literature of *The Framework for Science Education*,(2011), *The Next Generation Science Standards*, (2013), and the Science, Technology and Engineering standards as reflected in the Indiana Academic Standards for Science, (2010).

The study qualitatively analyzed 4 types of teacher knowledge:

- Procedural – content knowledge
- Inquiry – skills and habits of mind of doing science
- Strategic – when, where and how to use types of knowledge and assemble cognitive operations (i.e. ability to emphasize cross cutting concepts and integrate knowledge into a meaningful lesson)
- Pedagogical – skill-based knowledge, knowing when, where and how to use knowledge in teaching situations (i.e. formatively assess student conceptual readiness and implementing strategies to move student's understanding forward)

The author offered little distinction between strategic knowledge and pedagogical content knowledge. The results of the analysis determined that teachers had average understanding of procedural and inquiry knowledge but were weak in strategic knowledge as they struggled to tie in content with other areas of science. There was also an indication of weakness in the area of PCK. Teachers showed strong knowledge of varied methods but lacked the efficacy to believe their conceptual approach would work. Teachers cited influencing factors such as lack of previous experience, difficulty doing science or paralleling the process of actual scientific research. After completion of an 80-hour summer institute, elementary and intermediate schoolteachers reported improved sense effectiveness (Cook et al, 2015). The professional development initiative centers on developing science and engineering practice (SEP's) capabilities in teachers, in accordance with the NGSS practices. Although the teachers had increased confidence in implementing the SEP's as a result of professional development, there is no indication that the professional development program required teachers to adopt student centered pedagogical strategies. However, implementation of SEP's implied that the classroom atmosphere is one that supports student centered learning. A gap in this study is the failure to examine which, if any, elements of the professional development were transferred to the classroom level.

An additional study on this same initiative (ISI) provides more details about the elements of PCK that teachers implemented in their classrooms. Chapman et al (2015), conducted classroom observations on five teachers, grades three through six, who participated in the Indiana Science Initiative. This study used a modified version of the Science Teacher Inquiry Rubric which measured the degree of alignment with inquiry methods. The research questions were: 1) How do teachers who have participated in the ISI professional development incorporate the essential features of inquiry into their science instruction while using the ISI-provided curricular models?; and 2) What do teachers perceive to be the influences that support and challenge their ability to incorporate the essential features of inquiry as they implement the modules? The results of the rubric indicated that posing questions and collecting and analyzing data were effectively implemented in the classrooms of the five teachers. The findings suggested that the teachers struggled with the scientific thought process. Once the data was collected, they demonstrated limited ability to formulate, evaluate and connect explanations to a broader concept. Teachers cited time management and difficulty with facilitating science instruction as instructional barriers. Teachers were not confident in their student's abilities to learn using the inquiry method. They also were not comfortable using the materials provided with the inquiry modules. This additional research provides a deeper understanding of the challenges faced by teachers as they shift pedagogical strategies and closely relates to the goals of the proposed study. Although it remains that the number of studies focusing on teacher perceived self-efficacy as they shift from teacher-centered to student-centered environments is scarce, there is even less information that explores what elements of PCK influence the classroom environment as a result of professional development. The next study explores the transition of teacher-centered classrooms to student-centered learning as a result of professional development in the area of SEP's.

A 2015 mixed-methods study by Haag and McGowan, examined the areas of professional development connected to improving teacher readiness as they prepared to incorporate the Science and Engineering Practices (SEP's) of the NGSS at the classroom level. The SEP's are:

- asking questions (for science) and defining problems (for engineering)
- developing and using models
- planning and carrying out investigations

- analyzing and interpreting data
- using mathematics and computational thinking
- constructing explanations (for science) and designing solutions (for engineering)
- engaging in argument from evidence
- obtaining, evaluating, and communicating information

These SEP's are designed to promote collaborative work, preparing teachers to be proficient in fostering student-centered learning. The authors cited the need for research on teacher readiness and motivation in applying the SEP's in their lessons. The main guiding question of this research is aimed at identifying the characteristics of teachers who feel well prepared to implement this NGSS practice. In addition, the researchers hoped to identify professional development needs as a baseline to guide teacher training as states begin to adopt new conceptually based standards. The Modeling Instruction Program integrates student centered teaching in which the students use models to support an argument based on evidence. Embedded pedagogical professional development models the teaching skills required to promote student discourse and structure lessons according to the model of the Learning Cycle. This program has been used since 1990 and cites over 7,000 middle and high school teachers as participants (Haag & McGowan, 2015). The Modeling Instruction Program has been identified by the U.S. Department of Education as an Exemplary K-12 Science Program. This study is aimed at rating the motivation of in-service teachers to adopt NGSS SEP's in their classroom. They also analyzed the feelings of readiness of these teachers towards implementation. The research questions asked: What are the characteristics of teachers who feel well prepared to implement the NGSS practices? Could these teachers become mentors for their peers as they proceed forward with adopting the NGSS practices?

This mixed method design quantitatively analyzed 710 teacher respondents with survey questions that asked them to rate the extent to which they felt prepared to implement the SEP's of the NGSS at the classroom level. The results were valued using a five point Likert scale. Teachers were qualitatively investigated for their perceived readiness and their level of motivation by responding to open-ended questions which were analyzed by coding and categorizing the teacher's comments.

The quantitative results revealed that teachers who participated in the Modeling Instruction Program felt more motivated to use the NGSS SEP's than those who did not have experience using Modeling. The difference was statistically significant. The qualitative piece revealed that non-Modeler teachers had misconceptions about what the SEP's were as evidenced by comments such as , "The engineering practices in the NGSS standards intrigue me, but I'm a science teacher, not an engineer"(p. 423). Of the respondents, 70% expressed weakness in the area of engineering and reported that they would like more professional development focusing on those practices. The study concluded that high school teachers who received an average of 90 hours professional development in Modeling felt more prepared to implement SEP's as compared to non-Modelers. Middle school teachers with an average of 64 hours of Modeling professional development also expressed more confidence implementing the NGSS SEP's than the non-Modelers.

The above review supports the positive relationship between professional development and teacher efficacy. However, the study does have notable limitations. The limitations of this research can be traced to the method of acquiring respondents. The respondents were selfselected from a National listserv, thereby reducing the randomness of the participants. Due to the nature of the study, the researchers did not obtain any classroom observations to determine if the elements of the NGSS SEP's were actually being implemented to fidelity. This study does not address the research relevant to the elements of PCK that influence conceptual teaching. However, this study does give an indication of how professional development centered on conceptually based standards affects teachers' willingness to shift their pedagogical strategies to a more conceptual framework.

The Report of the 2012 National Survey of Science and Mathematics Education (NSSM) provides up-to-date information which identifies educational trends in the realms of teacher educational experience, curriculum and instruction, in addition to the availability and use of instructional resources. The NSSM has been collecting data and generating information pertaining to educational trends since 1977. This report explores a wide range of topics that address school culture such as demographics, available resources, and opportunities for teachers to develop knowledge. The applicable research questions of this report are:

1. To what extent do science and mathematics instruction and ongoing assessment mirror current understanding of learning?
2. What influences teachers' decisions about content and pedagogy?

The research design included selecting sample schools, both private and public. This study required in-depth information collected through teacher surveys regarding curriculum and instruction. For each school selected, a single teacher participated by reporting the required information for a single, randomly selected class. The returned surveys indicated that science teachers at all grade levels largely agreed with the following statements as influencing their decisions about content and pedagogy:

- Students should be provided with the purpose for a lesson as it begins.
- Most class periods should include review of previously covered material.
- Most class periods should provide students opportunities to share their thinking/reasoning.
- Most class periods should conclude with a summary of the key ideas addressed in that lesson (NSSME, 2013 p.20).

The data indicate that most middle and high school teachers feel prepared to teach science content however teachers at higher grade levels feel better prepared. Two additional trends emerged regarding teacher preparedness. Both middle and high school teachers responded that they feel less prepared to formatively assess their students. The study refers to formative assessment as “pre-instruction”, finding out what students already know and anticipating the areas of difficulty. Also, an emerging trend indicated that teachers who teach high achieving students feel better prepared as an instructor than those who teach low achieving students or who practiced in a school whose student population is predominantly from a low socioeconomic background. The data also indicated that few science teachers at all grade levels feel well prepared to teach the engineering practices which are a key strand of the NGSS. Summarizing this research as it relates to the proposed study concluded that the respondents believed it is important to teach using the methods of the NGSS however, teacher efficacy, or as referred to in the above study, teacher preparedness, remains low, particularly for those science educators in low socioeconomic districts. The limits of this study included possible bias in teacher selection. If administrators chose their best teachers to participate, the randomness of the selection would be compromised. A lack of qualitative data such as lesson plans, observations and interviews aimed at uncovering the degree of fidelity in which teachers implement conceptual methods represented a gap in the research. This concluding study on professional development and teacher efficacy re-emphasized the need for research surrounding the issues of reform-based professional development. The next section of this literature review is designed to connect reform-based professional development for teachers and evaluate the impact that this training has on student achievement.

Professional Development and Student Achievement

The following research literature will address reform-based professional development using conceptual change models and the impact on student achievement. The first article is a study conducted in 2014 by Johnson and Fargo which deals directly with the Transformative Professional Development (TPD) model and student achievement. This two-year intervention also incorporated Culturally Relevant Pedagogy (CRP) as this study is specific to elementary schools with a high percentage of Hispanic students. CRP is incorporated into the inquiry process of TPD by drawing on culturally relevant pre-conceptions and experiences. The three goals of TPD were:

- Integrate CPR with effective science teaching strategies as identified by the National Science Education Standards (NSES) with a focus on literacy and home language that supports students' conceptual understanding.
- Enhance a supportive learning community among teachers, students and professional development facilitators.
- Create a culture of learning by establishing high expectations and engaging students in scientific discourse (Johnson & Fargo, 2014).

The author identified the research method as a case study, however the only data published is a quantitative statistical comparison of a treatment group and a non-treatment group based on the outcome of a state mandated standardized test. The statistical methodology included a group of elementary teachers from two different schools, both classified as low socioeconomic status with most Hispanic students. The participant pool was composed of three teachers from a fourth-grade classroom, three teachers from a fifth-grade classroom and four teachers from a sixth-grade classroom. The goal was to transform teaching and learning of science through enhancing teacher effectiveness. Teacher effectiveness was measured through student achievement based on student performance of the state-mandated Criterion Reference Assessment (CRT). The professional development key components were a two-week professional development summer workshop, a three-day academic year workshop and monthly support visits for two consecutive years.

The CRT was evaluated for proficiency over time, comparing the TPD group to a non-intervention group. The data was analyzed using a binomial longitudinal multilevel statistical model assessing the binary outcome as either proficient or non-proficient. The results indicated a statistically significant increase over time for the TPD treatment group as compared to the non-treatment group. Although the professional development model is based on a conceptual change framework, it also incorporated CRP geared specifically to Hispanic students. It is unclear what effect this added component played in student achievement or if this model is transferable to classrooms composed of other demographics. The findings of this study were also limited by the small number of participants.

A more comprehensive study using the Bybee Learning Cycle Model (2006) advocated a student-centered learning approach which is very similar to the Bybee 5E Model published in the

2015 ACOS. Both models encompassed the spirit of conceptual learning by emphasizing an inquiry approach as a method of fostering critical thinking and understanding of the nature of science. This study explores how professional development for the Teaching Science as Inquiry (TSI) model impacted student and teacher content knowledge, student understanding about the nature of science, and fidelity of teacher implementation of the TSI model (Seraphin et al, 2014).

The participant pool was composed of 62 teachers, four teacher leaders and 1,176 middle school and high school students. An aquatics course was taught using the TSI method designed to incorporate four major scientific concepts from physical, biological, chemical, and aquatic science. Prior to classroom instruction, teachers participated in a two-day workshop, learning the conceptual approach of each of the four modules, resulting in a total of eight days of professional development. In addition, as ongoing support, teachers participated in one face-to-face follow-up and one on-line follow-up per module.

This year-long study collected data using a pre-test, post-test design. Questionnaires and assessments were administered at the beginning of the academic school year and after the conclusion of the last professional development workshop. The instruments used included questionnaires, interviews, and teacher fidelity measures that were validated using internal methods. The need for internal validation arose from the modification of these instruments from existing instruments previously deemed valid and reliable. The quantitative results were analyzed using a multilevel statistical model for the purpose of evaluation change along demographic lines. This analysis suggested a statistically significant positive effect on teacher and student understanding of the scientific process. Significant gains in content knowledge for all of the four models were also reported for both teachers and students. Teacher data supported a positively significant gain in teacher self-efficacy for using inquiry methods. Although this particular article is reviewed in the context of professional development and student achievement, it is important to note that it also adds to the body of research that explores teacher efficacy during the transition from teacher centered classrooms to student centered learning. The parameters of the above two studies exemplify the need to provide teachers with professional development in conceptual pedagogical strategies in order to foster student achievement and promote teacher efficacy.

Research Instruments

Cresswell & Clark, (2007) defined mixed methods research according to the following statement:

> Mixed methods research is a research design with philosophical assumptions as well as methods of inquiry. As a methodology, it involves philosophical assumptions that guide the direction of the collection and analysis and the mixture of qualitative and quantitative approaches in many phases of the research process. As a method, it focuses on collection, analyzing and mixing both quantitative and qualitative data in a single study or series of studies. Its central premise is that the use of quantitative and qualitative approaches, in combination, provides a better understanding of research problems than either approach alone (Cresswell & Clark, 2007, p.5).

The above statement is a general description of the depth of understanding that a mixed methods design can contribute to research. However, strategically choosing the proper design will add maximum value to the emerging knowledge. Cresswell & Clark outlined six prototypes of mixed methods designs:

- Convergent Parallel

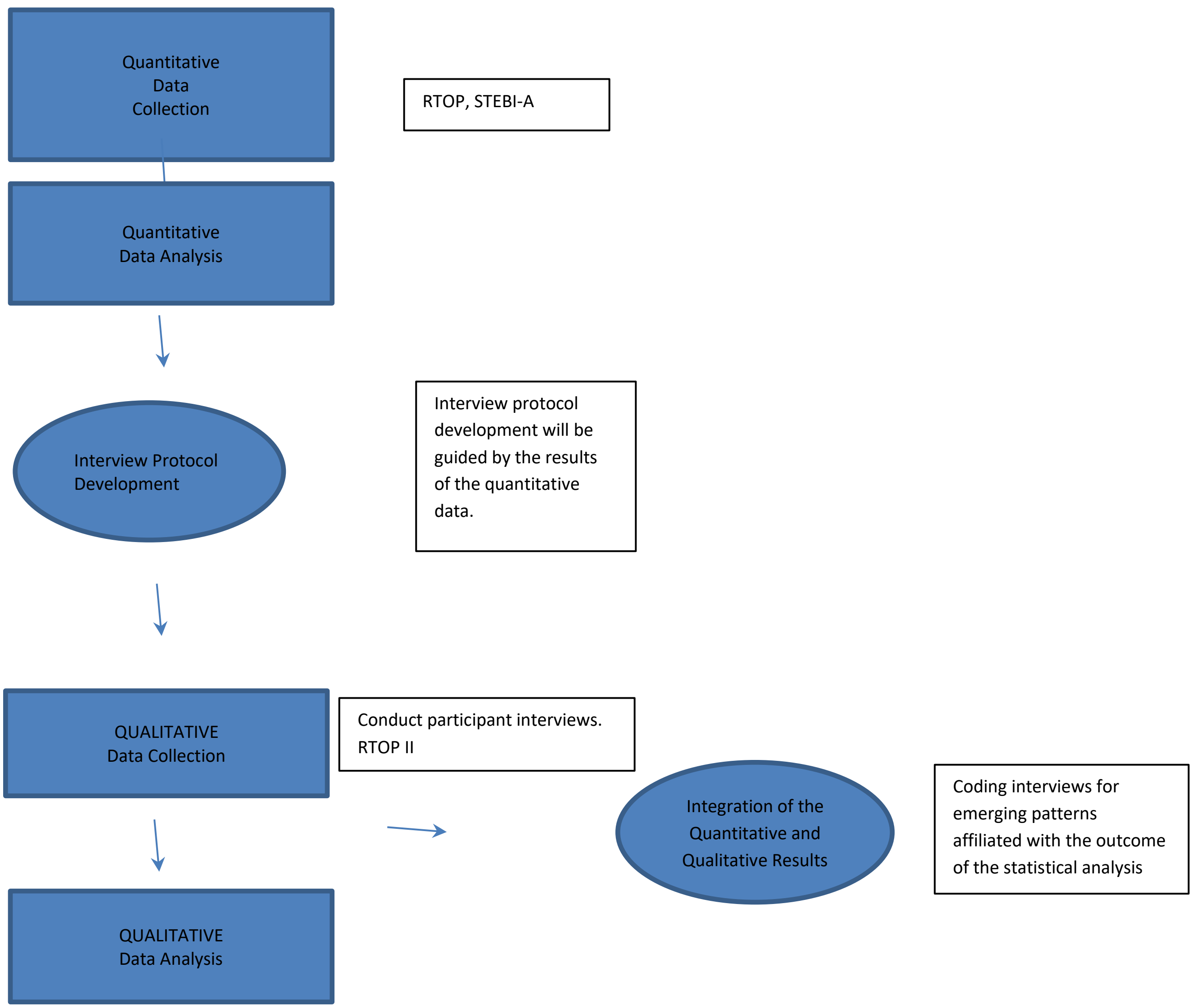
- Explanatory Sequential
- Exploratory Sequential
- Embedded Design
- Transformative
- Multiphase

The foundation of this research is grounded in using quantitative instruments to categorize teachers according to their degree of reform classroom practice. Understanding the patterns revealed by these measures was explored by using qualitative means. The Explanatory Sequential Design was determined as the best fit for this goal of this research.

The following diagram shows the phases of the Explanatory Sequential Design with the appropriate placement of the quantitative instruments and the qualitative component used in the research (Creswell & Clark, 2011, p. 121).

Diagram 1

The Explanatory Sequential Design



The above diagram is adapted from Designing and Conducting Mixed Methods Research (Cresswell & Clark, 2011, p. 121).

Examples of Mixed Methods Design

The choice to incorporate the Explanatory Sequential Design is guided by the need to strengthen insight into the elements that influence teachers to transition from traditional methods of teaching to reform based practices. Utilizing quantitative and qualitative data as a means of enhancing the research findings provided a more detailed understanding of the elements of PCK that teachers demonstrated in their classrooms. The evidence gained using quantitative results and qualitative inquiry, provided insight into predictors and barriers of reform teaching and contributed to hypotheses for further research. The following two research reviews exemplify the pragmatic value of using a mixed methods approach for a deeper understanding of teacher's knowledge structure and classroom practices.

A 2014 mixed methods study by Bartos and Ledman investigated the challenges that teachers encounter as they incorporate their knowledge structure of the Nature of Science (NOS) and Scientific Inquiry (SI) into their classroom practices. The purpose of the study was to understand teachers' knowledge structure of the NOS and SI and investigate how these concepts were communicated at the classroom level. The data was collected using a two-phase approach. In phase one, the researchers administered the Knowledge Structure of Nature of Science and Scientific Inquiry (KS4NS) instrument. This instrument was used to collect data on individual knowledge structure regarding teachers' understanding of the relationship between the nature of science and scientific inquiry ("Ark of Inquiry", 2017). Phase two consisted of classroom observations and related data collection which included lesson plans, worksheets, etc., to identify classroom practices that indicate an understanding of the connection between the NOS and SI. The results indicated that the KS4NS questionnaire was a predictor of the congruence of teachers' knowledge structure and their observed classroom practice. It is important to note that although it is recommended that the KS4NS is followed up with an interview, the researchers chose to follow up with classroom observations and articles of classroom practices such as lesson plans and evaluation documents. As suggested in the study an interview may have deepened the understanding of the teachers' thinking as they integrated the NOS and SI in their classroom practices. However, the structure of this research fits the Explanatory format.

A 2011 mixed methods study by Luft, et al, is more closely aligned with the methods and goals of this research project. The research premise is to understand the changes in pedagogical content knowledge (PCK), beliefs, and practices of first year teachers as they participated in a science induction program designed to strengthen their beliefs. The following questions guided the study:

1. What are the beliefs, PCK, and instructional practices of beginning secondary science teachers over the course of their first two years in the classroom?
2. How does participating in an induction program impact the change in beliefs, PCK, or instructional practices?
3. What contributes to or constrains the development of beginning science teachers during the first two years of their induction experience?

Three sets of data contributed to the results of this study. The first data source was the implementation of the Teacher Belief Interview (TBI). This instrument is a seven question semi-structured interview which includes coding maps. The purpose of this instrument was to gain insight into the epistemological beliefs of teachers (TBI: Luft and Roehrig, 2007). The second form of data collection was the PCK interview. This interview followed the similar protocol as the TBI and was used to identify the teachers' knowledge of student learning as well as their knowledge of instructional strategies. The third form of data was collected through observations of classroom practice. Using the Collaboratives for Excellence in Teacher Preparation Core Evaluation Classroom Observation Protocol (CETP-COP), the researchers were able to capture the practices of the participants over a two-year period using multiple quantitative and qualitative strategies.

In accordance with the mixed methods approach, researchers analyzed the TBI and PCK scores which used inferential statistics calculated intermittently over the course of the study. The results of the quantitative piece indicated that all teachers changed their beliefs towards a more conceptual understanding of student learning during the study. The PCK analysis showed a trend towards more student-centered teaching during the second year of induction. The qualitative portion of the study consisted of interviews conducted throughout the study. The qualitative portion provided valuable insight into the experiences that caused a shift in pedagogical strategies. For example, one participant interview revealed that she began “stressed out” attempting to find resources and materials for lessons, but eventually gained confidence and began to just focus on the craft of teaching. It is evident from the information gathered in this study that the mixed methods approach, which is descriptive of the Explanatory design, offered a deeper and more insightful picture of teacher development than either a qualitative or quantitative approach alone could achieve. The complementary nature of this design is the most appropriate vehicle to address the goals of this study.

Summary

This conclusion of the review of literature is applicable to the relationships between reform pedagogy and student achievement, pedagogical content knowledge and teacher efficacy, teacher efficacy and student achievement, and professional development and teacher efficacy. As all reform efforts are judged in light of student achievement, it is essential to look at the many variables such as PCK, conceptual change/reform instruction, teacher efficacy and professional development as a function of this success. This review supports the idea that reform efforts need to be school-wide, system wide and state-wide initiatives that must consistently work towards improving science education. This review also highlights the challenges that teachers face as they transition from traditional classroom instruction to a conceptual model based on the constructivists' framework while at the same time, are being accountable for student achievement. Considering the push for student achievement, teachers are seldom allowed a learning curve to become proficient when implementing conceptual change strategies. This national push towards moving science classes away from traditional teaching methods and towards the practices of reform education will require professional development and ongoing classroom support for in-service teachers. The goals of this research were to identify what elements of PCK science teachers need to develop as they move towards the reform approach. Additional domains include: What characteristics of the reform model are implemented to fidelity at the classroom level? How many teachers are proficiently teaching reform methods? What changes in teacher thinking promotes movement from teacher-centered learning to student-centered learning? How does teacher efficacy impact reform teaching?

CHAPTER 3

METHODOLOGY

As a Biology Specialist for Alabama Science in Motion (ASIM), I am in the unique position of observing the perceived readiness of teachers to implement reform-based standards, both in the classroom and during professional development. My experience in the capacity of a professional development facilitator and a classroom resource/support person has provided me with a two-dimensional insight into how teachers incorporate their professional development experience into their classroom structure. The question to be answered is, *Why do teachers with similar reform-based professional development experience vary in their degree of reform classroom practice?* This overall question will be explored through quantitative and qualitative data collection and analysis relevant to the following research questions:

1. To what extent are biology teachers implementing reform based instructional practices in their classrooms?
2. What factors influence biology teachers to abandon reform education strategies and default to traditional methods of teaching?
3. What factors predict whether biology teachers will use reform strategies in the classroom?

Context for the Study

The following is a description of the ASIM professional development program from which the pool of participants will be selected. ASIM is a state funded initiative that offers professional development using a lab based 5E Instructional Model. ASIM professional development applies the three dimensions of the NGSS to lab experience that matches the standards of the 2015 Alabama Course of Study (ACOS). The ASIM model incorporates the three-pronged premise of:

- providing professional development
- providing resources for teachers
- providing on-going classroom support which includes academic coaching and/or co-teaching

The following items highlight the benefits of becoming an ASIM certified teacher:

- access to cutting edge technology resources
- access to fully prepared lab kits delivered directly to classrooms
- academic support from ASIM Biology, Chemistry or Physics Specialists who have been trained to promote collaborative teaching for conceptual change

Biology, Chemistry and Physics professional development through ASIM consists of a two-year program of five consecutive days of summer training in conjunction with three to five days of embedded training during the school year. Summer training is geared towards mastering 5E Model labs that correlate with the standards of the 2015 ACOS for science. The embedded school year training is focused on using the labs to enhance content knowledge and practice reform classroom skills in real time. Year three attendees collaborate with new teachers in the capacity of mentor and/or teacher leader (Alabama Science in Motion, 2017).

During a recent introductory workshop for the 2015 ACOS, many teachers appeared frustrated and unengaged as we unpacked the standards, emphasizing the three dimensions of the NGSS. Observational evidence suggested that these teachers did not fully comprehend the conceptual framework of the 2015 ACOS standards or recognize how these standards connected to the NGSS. Observations also revealed teacher trepidation towards implementing the pedagogical skills of student collaboration required to effectively execute the standards to fidelity. As part of my professional duties, I am often present in classrooms, coaching, co-teaching or facilitating labs. During this time, I observed the struggles that teachers faced as they attempted to implement the three-dimensional standards and create a collaborative, student centered environment. Although ASIM provides resources for implementation of a reform-based model, observational evidence suggests that very few science teachers utilize these resources to support reform teaching. It has been observed that teachers will use parts of the resource kit for specific activities independent of the reform-based protocol.

The purpose of this study was to examine the elements of professional development teachers implement in their classrooms as they craft their instruction based on the three dimensions of the NGSS framework. The assumption is teachers who participate in professional development focused on teaching science standards by using reform methods are more likely to implement reform teaching strategies in the classroom. By comparison, it is assumed teachers who have not participated in such programs are less likely to implement these same strategies. Teacher efficacy was examined as a factor related to the willingness of teachers to implement reform methods. The effectiveness of implementation was also a consideration. The above assumptions are the backbone of the general research questions which explored the impact of professional development on inquiry reform practices in biology classrooms. This research also explored the effect of teacher efficacy on the implementation of reform practices. In addition, predictors and barriers impacting the level of reform practice in science classrooms were explored as variables. These research questions are addressed in further detail within the context of this chapter.

Research Design

The decision to conduct a mixed-methods study is driven primarily as an effort to better understand the complex factors inherent in social science research. By hearing the voices of participants, this researcher enhanced her understanding of the relationship among the variables of the study. The benefits of the mixed method approach addressed the following needs: one data source may not be enough to explain the initial results. Generalized exploratory findings enhance a study with a second method (Cresswell & Clark, 2011). Cresswell and Clark more specifically described the Explanatory Sequential Design, "The first phase involves collecting and analyzing quantitative data. Based on a need to further understand the quantitative results, the researcher implements a second, qualitative phase that is designed to help explain the initial quantitative results" (p. 119). Mixed methods research also presents a unique set of challenges. This approach requires two different methodologies, so the time involved to collect and analyze data can be extensive.

This study was focused on a small sample size of 15 participants. The first phase of this study used quantitative data to place teachers in categories based on the level of reform practice as measured by the Reform Teaching Observation Protocol (RTOP). The data from the second quantitative instrument, Science Teaching Efficacy Belief Instrument for In-service Teachers (STEBI-A), was analyzed as a possible predictor of reform practice. The second phase, or qualitative phase, coded observation and interview themes that were shared among participants but unique to each group. Cross integrating phase one and phase two helped explain and add depth to the results.

Participants of the Study

The 15 participants of this study were randomly selected from three different Local Education Agency (LEA) regions in the Southeast United States. Each participant was a high school life science teacher. The subject group's classroom experience ranged from two to twenty-three years. These teachers shared similar educational and professional development backgrounds. The classroom demographics were also similar. All the schools were in a county district except for one city school. Most of the classes observed were a diverse population of students whose ethnic origins appeared to be mainly; White, African American and Latino. The city school's student population mainly appeared as African American and one county school had a population that appeared to be mainly White students. The schools were located in middle to low income areas. Ethnicity and Socio-Economic Status (SES) could not be positively verified due to lack of access to school records.

Data Collection and Instruments

The explanatory sequential mixed-methods design was applied to a sample of teachers who were ASIM certified and attended ten days of reform based professional development, post 2014. Participants were selected using the "fish-bowl" method. This method is described as placing all eligible teachers' names in a container and blindly selecting potential candidates.

The following is a review of the data collection methods chosen to test the research questions that drove this study. The data collection methods included valid and reliable survey instruments, the Reform Teaching Observation Protocol (RTOP) and the Science Teacher Efficacy Belief Instrument for In-Service Teachers (STEBI-A) (Appendix: D). The RTOP evaluation instrument is aligned with the NRC reform teaching, research-based philosophy that "select teaching and assessment strategies that support the development of student understanding and nurture a community of science learners" (Bybee, 2010, p. 81). The RTOP protocol is designed to capture the characteristics of the modern reform teaching movement grounded in constructivism. This instrument is a common research measure of reform teaching for science, math and the new national standards (Piburn & Sawada, 2000). Below are listed five sources of validity that qualifies the RTOP as a qualified source to measure the elements of reform teaching:

- the Horizon Research 1997-98 Local Systemic Change Revised Classroom Observation Protocol
- the "standards" in science and mathematics education [NCTM's Curriculum and Evaluation Standards (1989), Professional Teaching Standards (1991), Assessment Standards (1995) and NRC's National Science Standards (1996)]
- the principles of reform underlying the ACEPT project
- the work of ACEPT Co-Principle Investigators, particularly that of Tony Lawson and the ASU Mathematics Education group led by Marilyn Carlson
- members of Evaluation Facilitation Group (EFG)

Based on a best-fit linear regression, the R^2 value for the Biology version of the RTOP is reported as 0.83. This value is indicative of an excellent reliability rating (Piburn & Sawada, 2000).

Research question one is directly related to sections III, IV and V of the RTOP. Effective teacher facilitation of a student-centered environment hinges on the degree to which teachers can develop a learning community in their classroom. Reform teaching is based on socially constructed knowledge, and all students must feel safe to express their ideas and contribute to whole group or small group discussions. This section models the process of a scientific community. Section III examines the degree to which teachers scaffold exploration experiences without formal presentation and how teachers encourage students to explore alternative approaches to problem solving and experimental design. A true learning community can lead to an unexpected path and teachers who meet the criteria allow students to originate and explore their own solutions to a general problem (Piburn & Sawada, 2000). Section IV rates the participants on how well they explore the depths of fundamental concepts. These fundamental concepts are akin to the NGSS cross cutting concepts that have been adopted by the 2015 ACOS for science. A strong conceptual understanding will be evident as students are able to relate their learning experience to broader concepts. Effective teaching for conceptual understanding requires teachers to have a strong grasp of the subject matter. Lessons that are designed for conceptual change will evaluate students' understanding by their ability to represent the phenomenon in a variety of symbolic ways and connect the phenomenon across disciplines using real world examples.

Section IV is Procedural Knowledge. Teachers who have mastered procedural knowledge will require students to incorporate a variety of methods demonstrating a clear understanding of a phenomenon. This section also evaluates the method that addresses the students' ability to make relevant predictions and offer reasonable solutions. Testing their predictions requires students to understand the proper experimental tools and the ability to design and critically assess an experimental procedure. Teachers who effectively demonstrate procedural knowledge allow students to reflect on their thoughts and learning throughout the lesson in a collaborative way. Procedural knowledge culminates in students' demonstrating intellectual rigor by critically discussing their acquired knowledge of a central problem using supporting evidence

Section V focuses on classroom culture where students communicate their ideas to others using several modes to present their findings. Teachers are expected to ask open-ended questions designed to promote deeper thinking or an alternate interpretation. This section is particularly dependent on student dialog where the students' questions or comments steer the direction of the discussion. This approach can only be effective if the teacher has successfully created a classroom culture of collaboration and confidence that all opinions will be met with respect. Students are encouraged to interpret evidence in a variety of ways and explore alternative solutions for addressing a phenomenon in a collaborative manner. The role of the teacher is a patient facilitator who does not give students answers but asks questions that help guide their understanding (Pilburn et al., 2000). RTOP sections III, IV and V are a collective measure of the elements of Pedagogical Content Knowledge (PCK). The following are RTOP Sample Observation Parameters

- Section III: The Instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.
- Section IV: The lesson promoted strongly coherent conceptual understanding.
- Section V: There was a high proportion of student talk and a significant amount of it occurred between and among students.

The STEBI-A is a teacher instrument that is designed for in-service teachers. Proficient modeling can transmit knowledge and transfer effective skills necessary for tackling unfamiliar demands. When faced with difficult tasks, individuals with higher perceived self-efficacy are more persistent in achieving their goals (Bandura, 1994). The STEBI-A is a valid and widely used instrument for the measurement of in-service science teaching efficacy (Riggs & Enochs (1990). Teachers who implement reform practice in their classrooms as a result of professional development show a higher mean score on the STEBI-A instrument (Lumpe, Czerniak, Haney & Beltyukova, 2012). The reliability rating for the STEBI-A is .91 as calculated using the best-fit linear regression, indicating that this instrument is an excellent tool for measuring teacher efficacy (Riggs & Enochs, 1989). The following are STEBI-A: Sample Rankings Statements

- When the science grades of students improve, it is most often due to their teacher having found a more effective teaching approach.
- I know the steps necessary to teach science concepts effectively.
- When teaching science, I usually welcome student questions.

Information gained from the above referenced instruments was used to craft specific interview questions that supported the broader research questions.

Data Analysis

The mixed method Explanatory Sequential Design for this research was implemented in two phases. Phase one was the quantitative phase that allowed identification of the general picture of the teacher's engagement in reform teaching as measured by the RTOP. The results from the RTOP assisted in forming categories of participants based on their level of reform practice. The researcher also measured the PSTE and STOE from data obtained using the STEBI-A. This data were analyzed as possible indicators or barriers to reform teaching. The second phase consisted of interviews with 14 teachers. The interview questions were based on observation data influenced by the RTOP results. The two phases were cross integrated. The qualitative phase was prioritized as this phase provided insight into the teachers thinking as well as providing evidence that supported the quantitative results and observations.

The first general research question: To what extent are biology teachers implementing reform based instructional practices in their classroom? was quantitatively explored using the

Reform Teaching Observation Protocol (RTOP). RTOP observations were recorded for two class sessions of the same students. The STEBI-A was administered prior to observations and interviews sessions were conducted after the second day of observations.

After determining the level of reform practice and grouping the participants, quantitative analysis was conducted as an average score for each group. Each RTOP category, Active Learning, Active Lecture and Traditional Lecture, contained 5 teachers. The average score for the quantitative variables (i.e. each quantitative RTOP category, PSTE and STOE) was treated as a single data point representing each group. This researcher presented the quantitative data by calculating the z-score and analyzing the distance from the mean as a measure of variation among the groups. This approach permitted the researcher to use a standardized measure of dispersion to identify which variables contributed to the overall disparity among the groups. Observational and interview themes were coded to determine any similarities or differences among the groups which may represent predictors or barriers of reform practice. This method of combining multiple sets of data adds depth to the findings by revealing commonalities and patterns (Write Content Solutions, 2017).

Table 1.

Research Questions Matrix

Question	Instrument	Analysis
General Question 1: To what extent are biology teachers implementing reform based instructional practices in their classrooms?	RTOP (part II, IV, V)	Quantitative – RTOP score based on Likert scale
General Question 2: What factors influence biology teachers to abandon reform education strategies and default to traditional methods of teaching?	Interview Protocol RTOP (part I &II)	Code interviews for emerging themes RTOP (setting, teacher background information)
General Question 3: What are the factors that predict if a biology teacher will use reform strategies in their classrooms?	Interview Protocol RTOP (part I&II) STEBI-A	Code interviews for emerging themes RTOP (setting; teacher background information) Bivariate Analysis

Research Timeline

The participants were observed for two days using the RTOP protocol. Teachers completed the STEBI-A prior to observations. Interviews were conducted post RTOP. Interviews and observations were coded for emerging themes. Data collection occurred during the 2018-2019 school year.

Summary

The mixed-methods design was an effective method for achieving the goals of this study. The RTOP measured the level of reform practices implemented by the teacher. The STEBI-A measured for teacher efficacy and was evaluated as a variable in the reform classroom based on the subsets of PSTE and STOE. Incorporating interviews and coding for emerging themes uncovered of PCK that influences reform practice. These findings may add to the body of research which explores elements related to teachers' pedagogical choices.

CHAPTER 4
PRESENTATION OF QUANTITATIVE AND QUALITATIVE DATA

The purpose of this chapter is to present the quantitative and qualitative data collected as a result of this mixed-methods study. Initially, I describe the process of selection for the 15 teacher participants and address deviations from the original proposal. This section also includes a description of the participants. Quantitative data, obtained from the Reform Teaching Observation Protocol (RTOP) and the Science Teaching Efficacy Belief Instrument for In-service Teachers (STEBI-A), are presented for the purpose of integration with qualitative strands. The qualitative strands are observation and interview data. The data presented in this chapter are used to answer the following research questions:

Description of Participant Selection

1. To what extent are biology teachers implementing reform based instructional practices in their classrooms?
2. What factors influence biology teachers to abandon reform education strategies and default to traditional methods of teaching?
3. What factors predict whether biology teachers will use reform strategies in the classroom?

As discussed in chapter 3, the data was collected from a sample of 15 teachers. These subjects were selected from three different state Local Education Agencies (LEA's). Each teacher was an Alabama certified Science in Motion (ASIM) teacher who had completed a minimum of ten days of reform based professional development, post 2014. Some deviations occurred from the original protocol. The following paragraph describes these deviations.

The three regions are identified as region B, region M and region A. Emails were sent to teachers in each region who met the criteria stated above. Several teachers did not respond to the emails. Additional emails were sent, however, response remained low. Due to lack of response the number of teachers per region deviated from 5 participants to the following final numbers; region B (7), region M (6) and region A (2).

A second deviation occurred in the selection process. The original method of selection was proposed as the "fish-bowl" method. However, due to lack of response, the researcher also used the snowball method of teachers referring other teachers as potential candidates. Three teachers were selected through snowball sampling. A third deviation occurred as one teacher from region A had a single day of classroom observation rather than two days due to a schedule change. This teacher was kept in the study resulting in one day of RTOP data. A fourth deviation occurred as a teacher from region M was not interviewed due to a personal conflict. Attempts to re-schedule the interview in a timely manner were unsuccessful due to school absence. This teacher remained in the study, which resulted in interview data for Group One decreasing from 5 teacher to 4 teachers. No other deviations from the original protocol occurred.

Description of the Participants

All the participants were biology certified Alabama Science in Motion (ASIM) teachers who participated in ASIM training. ASIM professional development provides content deepening, in the areas of biology, chemistry and physics using reform methods grounded in the three-dimensions of the Next Generation Science Standards (NGSS). All certified ASIM teachers have access to fully prepared kits, equipment and lab protocols which are designed using the reform model as described in the 2015 Alabama Course of Study for Science.

The teachers were divided into three groups based on their RTOP scores. The RTOP range for each group is as follows: Active Learning (50+), Active Lecture (30-49) and Traditional Lecture (0-29) (“The Classroom Observation Project”, n.d.). The following table is a snapshot of teacher descriptors in the context of their group.

Table 2, Table 3, and Table 4 contain acronyms identifying professional development programs. These programs are identified as follows:

Alabama Science in Motion (grades 9-12) – ASIM

Alabama Math Science and Technology Initiative (grades k-8) – AMSTI

Hudson Alpha Institute of Biotechnology – HAIB

Claims, Evidence and Reasoning – CER

Table 2

Teacher Background Descriptors – Group One, Active Learning

Snapshot Data BP1	MP1	MH2	MT1	MH1	
RTOP Score	75.5	64	63.5	63	74.5
Years of Teaching Experience	23	5	18	17	7
Highest Degree(s) Earned	MA Biology Education	MA General Science, MA Health Administration	AA, EdS Secondary Science Biology	MA Biology Education	MA Biology Education

Subject Observed	Anatomy	Biology	Biology	Biology	Biology
Influential Professional Development	ASIM	ASIM HAIB	ASIM HAIB	ASIM HAIB	ASIM HAIB Southern Research Internship
Work Experience Outside of Classroom	Research Tech (8 years)	Health Administration (8 years)	none	none	None

Table 3

Teacher Background Descriptors – Group Two, Active Lecture

Snapshot Data BP1	BP2	BCC2	BSV1	AH2	
RTOP Score	49.5	48.5	47.5	33	35.5
Years of Teaching Experience	7	3	2	13	6
Highest Degree(s) Earned	MA Science education	BA General Science	MA General Science	MA General Science	MA Biology
Subject Observed	Biology	Biology	Biology	Biology	Biology
Influential Professional Development	ASIM HAIB	ASIM HAIB BioTeach	ASIM HAIB	AMSTI ASIM	ASIM HAIB
Work Experience Outside of Classroom	Retail, child care	n/a	Forestry	Retail	n/a

Table 4

Teacher Background Descriptors – Group Three, Traditional Lecture

Snapshot Data	AH1	BF1	MH3	BCC1	BOG1
RTOP Score	28.5	18.5	9.5	10	20
Years of Teaching Experience	4	6	4	17	11
Highest Degree(s) Earned	BA Education Biology	MA General Science	BA General Science	MA Biology	MA General Science
Subject Observed	Biology	Biology	Biology	Biology	Environ-mental Science
Influential Professional Development	ASIM	ASIM AMSTI	ASIM HAIB	ASIM AMSTI	ASIM HAIB CER
Work Experience Outside of Classroom	Farmhand	n/a	n/a	Military, Cell Research	n/a

Group 1 - Group One was identified as those teachers who effectively promoted active learning in their classrooms. Students in these classrooms typically engaged in problem-based learning using abstract data. Students were expected to interact with each other, engaging in in-depth discussions. The teacher confidently assumed the role of facilitator, prompting students to craft a hypothesis and design their own experiments (The Classroom Observation Project, n.d.).

The years of teaching experience for this group varied from five to 23 years. Every teacher in this group held a minimum of a master's degree. All the teachers had similar professional development backgrounds. As mentioned earlier in this chapter, certification in

ASIM is the common reform based professional development program that was a requirement for teacher selection. Four of the five teachers had also attended Hudson Alpha Institute for Biotechnology (HAIB). The Hudson Alpha Institute for Biotechnology described their professional development program as a hands-on and content deepening experience designed to help teachers implement the 2015 Alabama Course of Study, specifically in genetics. Two of the five teachers in G1 had careers prior to entering the classroom.

Group 2 – The teachers scoring in this group are characterized as employing an active lecture style of teaching. The Classroom Observation Project (n.d.) described instruction, or this ranking as transitional whereas student interaction consists of short guided exercises. At least 50% of the content is transmitted through lecture. Students regularly interact with diagrams, graphs and models; however, activities are short. Students engage in student-centered discourse approximately 10% to 15% of the time.

Years of teaching experience ranged from two to thirteen years. Four of the five teachers hold a master's degree, one teacher's highest degree is Bachelor of Science. As in Group One, this group also had a very similar professional development history that is reflective of the same professional development programs cited by Group One. One teacher had additional professional development with Alabama Math, Science and Technology Initiative (AMSTI). Two of the five teachers had prior work experience before entering the classroom.

Group 3 – This group is identified as those instructors who primarily engage in traditional lecture. In addition to a primarily lecture based format, characteristics of this group are exemplified by the types of questions the teacher asks. Most of the questions were straightforward, requiring one-word answers or short explanations. Students rarely generated their own questions and rarely interacted during class.

Years of teaching for Group Three ranged from four to 17. The professional development for this group deviated from Group One and Group Two. Two participants had attended HAIB workshops and two other participants attended AMSTI training. Two of the five participants in Group Three had careers prior to becoming a classroom teacher.

Quantitative Data

The following RTOP evidence was used to address question one: To what extent are biology teachers implementing reform based instructional practices in their classroom

Table 5

RTOP Scores

Participants Score	III. Lesson Design and Implementation	IV. Content	V. Classroom Culture	Total
AH1	3	19	6.5	28.5
AH2	12	8	13	33
MP1	13.5	26.5	35.5	75.5
MH1	7.5	22.5	33	63
MH2	9	21.5	33.5	64
MT1	8.5	25.5	29.5	63.5
MT2	5.5	17.5	12.5	35.5
BOG1	1.5	10.5	8	20
BCC1	0	9	1	10
BCC2	8.5	15	25	48.5
BSV1	6	21	20.5	47.5
BF1	2	9.5	7	18.5
BP1	8.5	32	34	74.5
BP2	12	16.5	21	49.5

The total RTOP score is the basis for categorizing the 15 participants into the three groups representing Active Learning (G1), Active Lecture (G2) and Traditional Lecture (G3).

These data were the foundation for analyzing both quantitative and qualitative relationships which will be discussed in chapter 5.

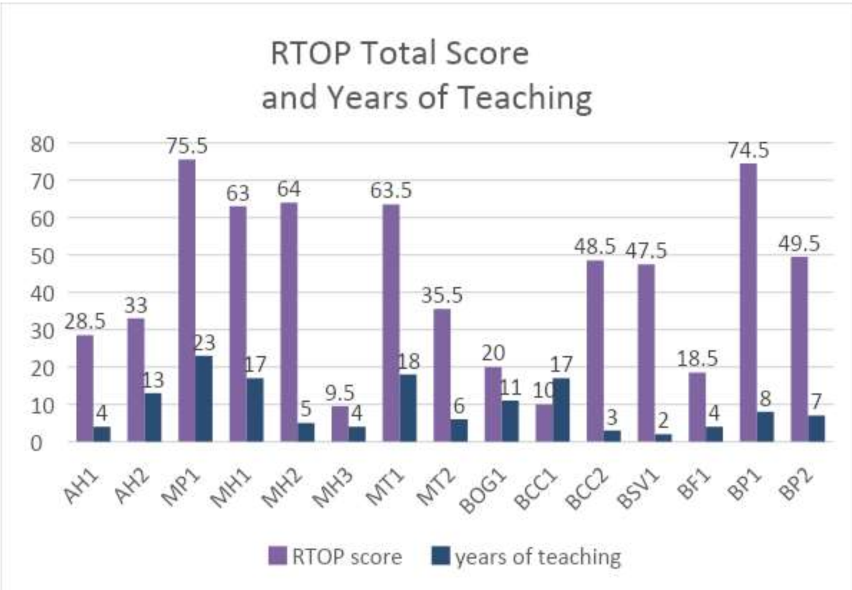
Table 6

RTOP Total Score and Years of Teaching

Participant	RTOP Total Score	Years of Teaching
AH1	28.5	4
AH2	33	13
MP1	75.5	23
MH1	63	17
MH2	64	5
MH3	9.5	4
MT1	63.5	18
MT2	35.5	6
BOG1	20	11
BCC1	10	17
BCC2	48.5	3
BSV1	47.5	2
BF1	18.5	4
BP1	74.5	8
BP2	49.5	7

Diagram 2

Teacher RTOP Score and Years of Teaching



RTOP Total Score and Years of Teaching Linear Regression r=.3085

Diagram 3

PSTE Distribution

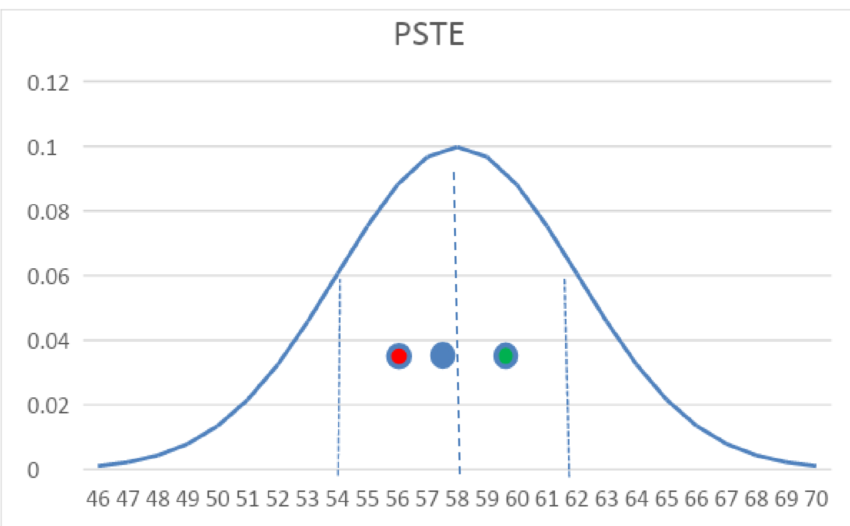


Table 7

PSTE z-scores

	z-score	Mean	SD
Group 1	-0.46	57.7	3.9
Group 2	-0.05		
Group 3	0.5		

Diagram 4

STOE Distribution

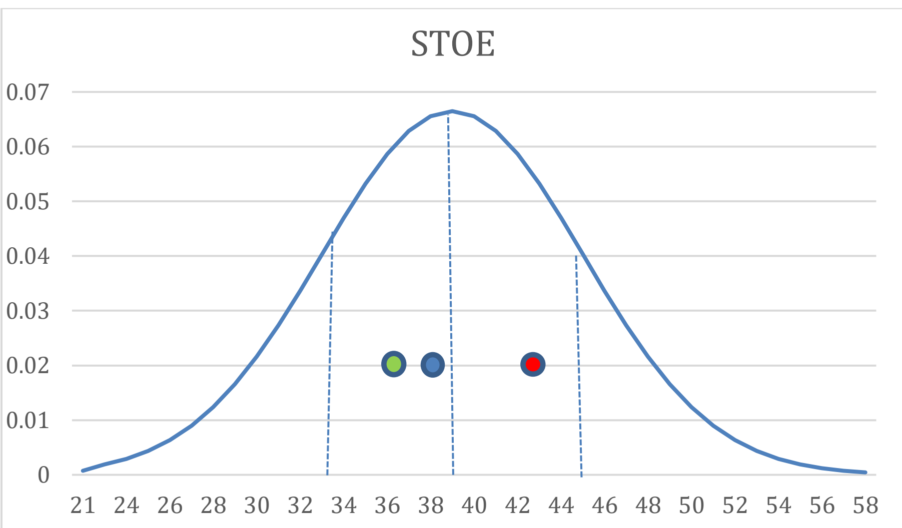


Table 8

STOE z-scores

	z-score	Mean	SD
Group 1	.69	39.3	6.18
Group 2	-0.11		
Group 3	-0.57		

Table 6 and Diagram 2 compare the relationship between the researchers' data of the total RTOP Score and years of teaching. Diagram 3 and Diagram 4 represent the subsets of the STEBI-A; Personal Science Teaching Efficacy (PSTE) and Science Teaching Outcome Expectancy (STOE). By plotting the z-score on a distribution curve, the researcher was able to compare the subsets for each group, relative to the distance from the mean (Table 7 and Table 8). This data were collected with the purpose of addressing the research questions: 2) What factors influence teachers to abandon reform education strategies and default to traditional methods of teaching? and 3) What are the factors that predict if a teacher will use reform strategies in their classrooms?

All statistical data were analyzed using the Microsoft Excel 2019 statistical analysis program. A linear regression model was used to analyze Diagram 2. Based on this model, the relationship between reform practice and years of teaching revealed a weak correlation (r=.3085). A comparison of the z-scores for each subset of the STEBI-A indicates that Group Two scored close to the mean in Diagram 2 (PSTE) and Diagram 3 (STOE). Group One and G3 reflect differences. Group One placed below the mean for PSTE while G3 placed above the mean. The reverse is observed for the STOE data, G1 placed above the mean while G3 placed below the mean.

This research explored an internal relationship within the three quantitative fields of the RTOP instrument. The three quantitative sections of the RTOP are; III. Lesson Design and implementation, IV. Content and, V. Classroom Culture. These three areas measure distinct teacher characteristics. The researchers compared the three fields to examine if any category contributed more than the others towards the disparity of the RTOP results among the three groups. The following table and diagram show a comparison of this data.

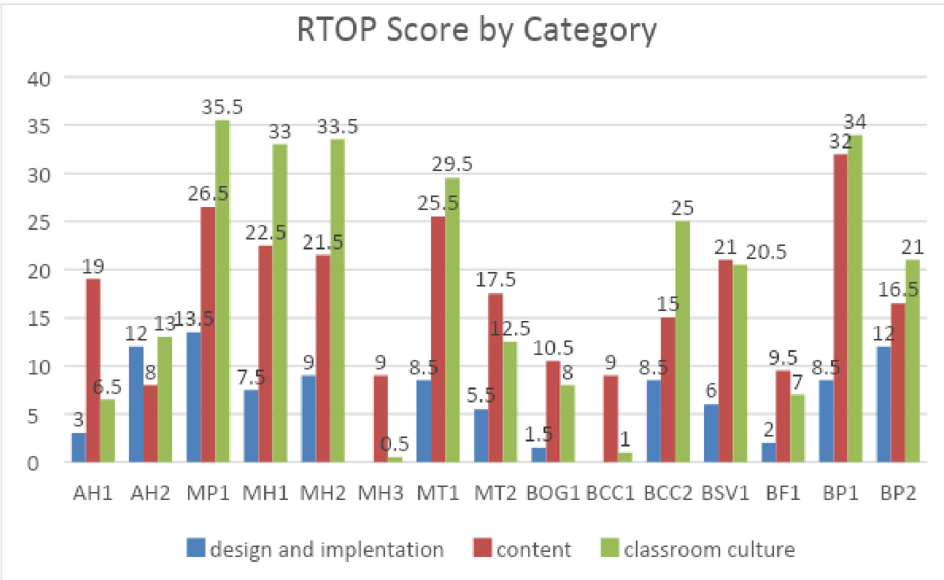
Table 9

RTOP Score by Category

Participant Score	III. Lesson Design and Implementation	IV. Content	V. Classroom Culture	Total
AH1	3	19	6.5	28.5
AH2	12	8	13	33
MP1	13.5	26.5	35.5	75.5
MH1	7.5	22.5	33	63
MH2	9	21.5	33.5	64
MH3	0	9	0.5	9.5
MT1	8.5	25.5	29.5	63.5
MT2	5.5	17.5	12.5	35.5
BOG1	1.5	10.5	8	20
BCC1	0	9	1	10
BCC2	8.5	15	25	48.5
BSV1	6	21	20.5	47.5
BF1	2	9.5	7	18.5
BP1	8.5	32	34	74.5
BP2	12	16.5	21	49.5

Diagram 5.

RTOP Score by Category



To understand the internal differences among the groups as they relate to the RTOP scores, the researcher calculated the average z-score for each category per group, then plotted these scores on a distribution curve as a method of comparing relative distances from the mean. The following tables and diagrams display the differences among the three groups for each RTOP category.

Table 10

z-scores for Internal RTOP Analysis

Group	RTOP III Lesson Design Average Z Score	RTOP IV Content Average Z Score	RTOP V Classroom Culture Average Z Score
1	.83	1.2	1.3
2	.68	-0.17	.074
3	-1.1	-0.76	-1.1

Standard Deviation	4.4	7.4	12.1

Diagram 6

Distribution Curve for RTOP III, Lesson Design and Implementation

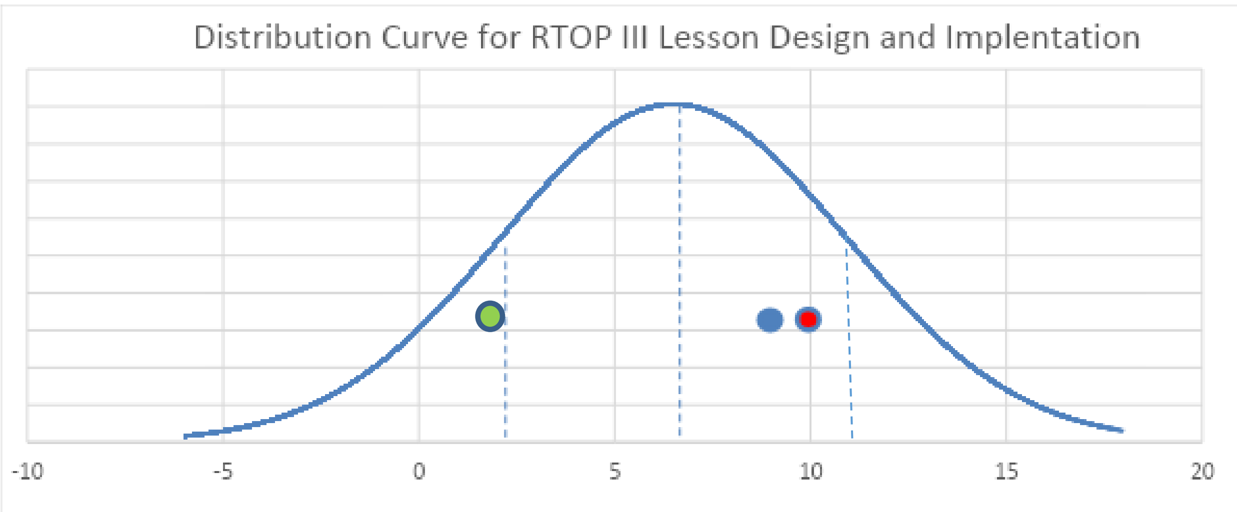


Table 11

z-score for RTOP III, Lesson Design and Implementation

	z-score	Mean	SD
Group 1	0.83	6.5	4.4
Group 2	0.68		
Group 3	-1.1		

Diagram 7

Distribution Curve for RTOP IV, Content

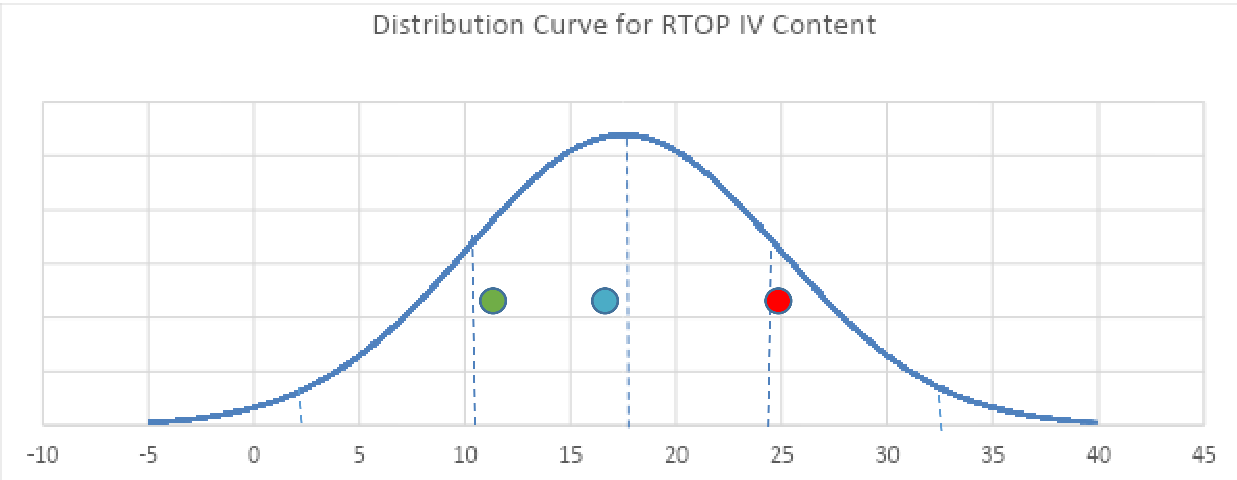


Table 12

z-score for RTOP IV, Content

	z-score	Mean	SD
Group 1	1.12	17.0	7.4
Group 2	-0.17		
Group 3	-0.76		

Diagram 8

Distribution Curve for RTOP V, Classroom Culture

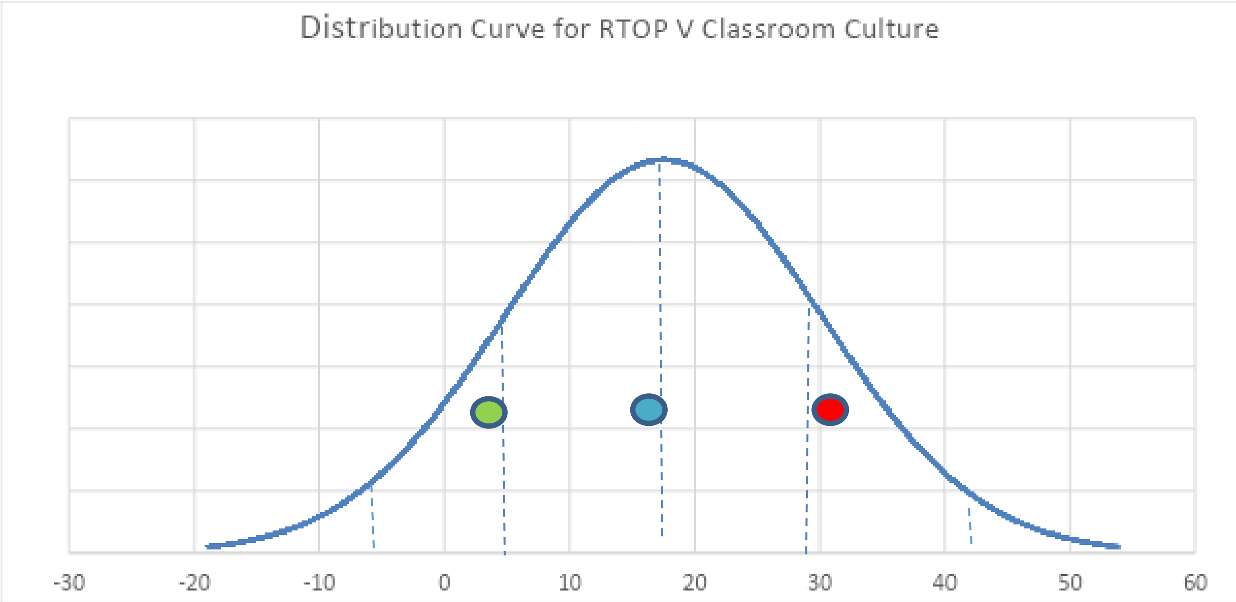


Table 13

z-score for RTOP V, Classroom Culture

	z-score	Mean	SD
Group 1	-1.3	17.5	12.1
Group 2	0.074		
Group 3	-1.1		

Comparing the standard deviation among the three groups indicated the largest z- score spread occurred in category V, Classroom Culture. These data revealed a disparity between G1 and G3 in each of the three categories, however, this researcher chose to focus on the category showing the most impactful implication. Justification for this choice was based on recognizing that category V had the largest SD value of 12.1. Also, the z-scores for both G1 and G3 placed two standard deviations from the mean. Lesson Design and Implementation contained five items for analysis. This researcher deemed the lack of quantitative data as unreliable, and therefore chose to eliminate Lesson Design and Implementation as an item for analysis.

The above quantitative analysis provides the data necessary to answer research question 1) To what extent are biology teachers implementing reform based instructional practices in their classrooms? In addition, these data also provide a foundation for addressing the factors in questions; 2) What factors influence biology teachers to abandon reform education strategies and default to traditional methods of teaching? And 3) What are the factors that predict if a biology teacher will use reform strategies in their classroom? In order to provide a more in-depth examination the researcher employed the Explanatory Sequential Mixed-Methods Design. This design is executed in two distinct phases. The first phase is the collection and analyzation of the quantitative data. The second phase is the integration of the qualitative data which is designed to provide insight into the initial quantitative findings (Creswell & Clark, 2011). In conjunction with the guidelines of this design, cross-strand integration explored the supporting themes further discussed in Chapter 5.

Qualitative Data

The quantitative analysis grouped the participants into three categories based on their RTOP scores. These groups remained in-tact during the qualitative data analysis. The RTOP range for each group is as follows: Group One (G1) - Active Learning (50+), Group Two (G2) - Active Lecture (30-49) and Group Three (G3) - Traditional Lecture (0-29). The sequence of presentation for the qualitative data begins with observations recorded in Section II of the RTOP; Contextual Background and Activities. Three main categories emerged: Teacher Observation, Student Observation and Classroom Environment. The category of Classroom Environment is discussed as a general characteristic and is not analyzed as a specific element of PCK affiliated with Classroom Culture. The table for Classroom Environment is not included in the body of this document. Along with other sub-themes, the researcher chose to decrease the volume of information by addressing only the themes applicable to the cross-strand integration used in the data analysis. The full scope of the themes and sub-themes can be found in Appendix D. Listed below are the sub-themes that have been integrated as evidence supporting the qualitative strands. Observational themes are presented in Appendix E.

Teacher observation themes

- act as facilitator
- asks probing questions
- facilitates whole class reflection
- lectures between 3 and 5 minutes

Student observation themes

- generates questions
- drives class discussions
- works effectively in groups with little teacher assistance
- actively engaged in exploring phenomenon (i.e. use of models, hands-on, discussion)
- freely asks questions in an informal manner

Interviews were also transcribed and coded for themes as an additional strand supporting the quantitative evidence. The interview themes are presented in Appendix F. These themes are: Evidence of Reform Teaching, Evidence of Traditional Practice, Evidence of Discomfort

Teaching 3D Standards, Evidence of Positive Classroom Culture and Evidence of Proficiency Teaching 3D Standards. The conclusion of this section is presented as a narrative which merges the observations themes and interview themes as general group trends.

Merging Observation Themes and Interview Themes for General Trends

Group One, Active Learning

Group One Teachers effectively employed reform teaching by engaging students. These teachers acted as facilitators asking probing questions. The teachers carefully listened to student responses before asking a question, causing the students to continue their thought process. Occasionally the teacher would use a question to launch a class discussion and facilitate whole class reflection. Lecture lasted between three and five minutes. Short lectures of five minutes or less occurred intermittently through the class period.

Many examples of positive student behavior were observed. Positive student behavior includes generating questions, student driven class discussions, working effectively in groups and actively engaging in exploring phenomenon. All the Group One classes freely asked questions in an informal manner. The idea of listening and communication skills fostering a positive classroom culture is explored as an indicator to reform teaching in Chapter V.

The interviews provided further evidence that the attitudes of Group One teachers towards education is grounded in a reform mindset. Only four of the five teachers in Group One were interviewed. All of the teachers interviewed described their own teaching in terms of a reform approach. Interview evidence of reform teaching was also addressed as teachers described their philosophy about student learning. A representative quote describes the general description shared by these teachers, “I think learning is the teacher facilitating content, activities and the students actively taking a part in the learning process". One of the four teachers interviewed referenced discomfort teaching the 3D standards as described in the 5E model.

Both quantitative and qualitative data support classroom culture as an emerging theme distinguishing the three groups. The following narrative summarizes the classroom culture of Group One. None of the Group One teachers described their classrooms as discordant. An Example of discordant classroom culture is described as teachers who identify their students as incapable of benefitting from pedagogy beyond traditional practice. Phrases such as "unable to understand the standards," "unprepared for rigorous lessons" or "lacking the social skills" are indicators of discordance. Three of the four teachers provided evidence that supports a positive classroom culture. The respondents described their relationships with students in terms of "worth it," "reaching out to students," " working with students," "give and take," "rapport with the kids," "partnership," "feeling comfortable," "building a relationship" and "feeling supported."

Participants were interviewed about their beliefs relating to the value of teaching the 3D standards. Three of the four teachers expressed confidence in teaching the standards and felt positive about the 3D structure. One teacher mentioned the short class periods as a barrier to teaching in this format.

Three of the four interviewees remarked positively about the support they received from their administration. One of the four teachers did not comment. No interview evidence suggested the teachers in this group had misconceptions of inquiry learning.

The researcher identified the general trend for group one teachers as facilitators of learning. This trend is supported by the RTOP score and observational data. In addition, the teacher interview responses reinforced the evidence that these teachers hold a belief of student learning as a partnership. The researcher identified the most distinguishing characteristic of this group as its ability to communicate with students in an informal and trustful manner as well as skillful listening which contributes to the classroom culture. This group also demonstrated purposeful skill in classroom organization fostering student interaction. These characteristics are further explored as predictors of reform education in Chapter V.

Group Two, Active Lecture

The observational data of Group Two supports the RTOP descriptive term, active lecture. The teachers in this group employed many reform strategies, however, they leaned heavily on a lecture format. Two of the five teachers acted as facilitators for a portion of the class period. Facilitator roles were generally employed for less than half of the class period. The remainder of class time consisted of lecture. All the teachers proficiently asked probing questions which stimulated deeper student thinking. However, this strategy seemed to be employed as a time dependent occurrence and not as an organic, spontaneous discussion that resulted in student driven questions. Two of the five teachers used student dialog as a formative assessment tool that led to further questioning by the teacher but did not evolve into a class discussion. Three of the five teachers employed whole class reflection. Negative student behavior was observed in three of the five classes. This behavior consisted of off task, distracted or disengaged students. Students in all classes worked effectively in groups and actively engaged in exploring phenomena, they also freely asked questions for a portion of the class period.

Interviews of this group aligned with the observations indicating a mixed or incomplete understanding of a reform teaching mindset. Three of the five teachers described their own teaching beliefs in terms of reform methods by using indicator terms and phrases such as “designing experiments,” “linking to evidence,” “understanding of tangible stuff.” “5E model,” “three dimensional,” “scaffolding.” The other two teachers described learning as adding new skills or concepts. None of the teachers in this group referenced traditional practice as a pedagogical strategy which indicates they may not be aware of their own practice and dependence on traditional methods. Two of the five teachers referenced discomfort with teaching the 3D standards. Evidence statements include, “I just don’t feel like I have the time” and “they are deep and take a ton of planning and resources.” Both teachers discussed time as a barrier and one of five teachers described teaching a class as “crowd control” referencing a degree of a discordant classroom. Two teachers referenced positive classroom cultures by describing their interaction with students as “openness,” “reflective,” “environment of safety and welcomes and love of acceptance.” None of the teachers in Group Two referenced proficiency in teaching the 3D standards by discussing the value of this approach. Three of the five teachers listed institutional barriers such as standardized testing, pushback from parents, time limitations, large class sizes and paperwork. Two of the five teachers mentioned positive administrative support although none of these teachers suggests their administration would prohibit pedagogical strategies connected to reform education. No interview evidence suggests the teachers in this group had misconceptions of inquiry learning.

The general trend of the Group Two teachers is identified as a belief in the value of reform education. These same teachers did not indicate an understanding of how the 3D standards supported their own stated philosophy. Observational data suggests that the Group Two teachers feel more comfortable lecturing which contrasts with their interview responses about student learning. Observationally, the pedagogical strategies that mimicked a reform classroom seemed to have been enacted as a diversion for students rather than a purposeful strategy to build student understanding. This suggests these teachers may harbor a misconception of the reform process. Like Group One, Group Two teachers generally had an open and trustful relationship with their students. The disconnect between teacher beliefs about learning and classroom practice is explored as a barrier to reform education in Chapter V.

Group Three, Traditional Lecture

Group Three quantitatively scored in the range of traditional lecture on the RTOP instrument which is supported by the observational and interview data. Five teachers were included in this group. The researcher did not observe any of these teachers acting as a facilitator. Three of the five teachers asked occasional probing questions but did not encourage further student dialog. Three of the five teachers engaged in whole class reflection. In accordance with the traditional lecture category, all the teachers engaged in lecture for all or most of the class period. A higher degree of negative student behavior was observed as compared to the previous two groups indicating a discordant classroom culture. An example of discordant classroom culture included several students in one class making disparaging remarks. In three classes, teachers were observed disciplining students with oral threats or moving seats. One teacher sent three students to the office for further disciplinary action. Disruptive students were observed in three of the five classes. Three of the five teachers had distracted students and disengaged students. Student generated questions were observed in one of the five classes, but the teacher did not use these questions to drive further discussion. Prior to asking questions the students raised their hands in order to be recognized by the teacher in a traditional manner. None of the classes engaged in group activities. Two of the five classes engaged in exploring phenomena by using models or hands-on materials in pairs and for short periods of time. In one class, students freely asked questions in an informal manner, however, the teacher promptly answered the questions rather than allowing these questions to guide the lesson.

Interview evidence reveals that two of the five teachers referenced engaging students in group efforts. One of the teachers used POGIL's as a whole group exercise and the other teacher collected class experimental data and employed whole class reflection. The frequency of these strategies was not revealed. None of these three teachers referred to their role in terms of acting as a facilitator or scaffolding inquiry experiences to promote student understanding of complex phenomena. In accordance with the RTOP score and observational data, four of the five teachers referred to the benefits of traditional teaching. These teachers used phrases such as

- told set of things
- I talk about…
- The habit of education is always keeping them entertained, a part of education is taking notes.
- If we just went back to the old way of teaching…
- I do use text quite a bit.
- The only labs that I do are something like a quick intro lab.
- Do some microscope work and look at specific slides.

Four of the five teachers expressed discomfort in teaching the 3D standards. Indicator descriptions include statements such as

- They're (students) are not ready for it….they're not prepared for the rigor.
- They really have a difficult time making that jump.
- I know modeling is what they need, I just get stuck on how they can do it.
- The standards are really advanced.

The general theme is the belief that their students cannot learn using the methods required to effectively teach the 3D standards. Four of the five teachers in this group made several references to a discordant classroom culture during the interviews. References include phrases such as

- I would like them to come to class prepared.
- What are they doing to motivate themselves?
- Their maturity level is a little low and that leads to disruptive behavior.
- I don't trust my children to do it (labs).
- It shouldn't take that long if they knew something about genetics before they came in.
- The kids this year are more difficult.

None of the five teachers referenced a positive classroom culture. None of the five teachers referenced proficiency in teaching the 3D standards. Three of the five teachers cited institutional barriers such as lack of technology resources, loss of preparation time, parents complaining and large class sizes. Two teachers commented positively on administrative support and one recognized support received from the community. None of the teachers indicated administrative support as a barrier to reform education. Misconceptions about inquiry learning were not recognized as a theme in Group One or Group Two; however, the researcher included this distinction as a characteristic of Group Three. Two of the five teachers in this group said they have their students do "different things every day," or "some type of activity every day." This is an indicator that these teachers are employing hands-on activities as a diversion strategy rather than as a scaffolding for learning targets.

The general theme for the Group Three teachers is that they rely primarily on traditional lecture as a teaching strategy. They share a belief that using the reform methods as required to teach 3D standards are too rigorous for their students. They do not trust their students in a lab setting. Group Three teachers find value in rote memorization as a landmark of traditional, objective-based lecture. In contrast with Group Two, who share a reform mindset but struggle with the skills of fully implementing a student -classroom, Group Three teachers share a traditional classroom mindset and value said methods. The value of traditional methods as a belief for best practice is discussed as a barrier to reform education in Chapter V.

The quantitative and qualitative data set forth in this chapter have provided a depth of information, which can be connected to cross-strand integration, related to the research questions:

2. What factors influence biology teachers to abandon reform education strategies and default to traditional methods of teaching?
3. What are the factors that predict whether biology teachers will use reform strategies in their classroom?

The variables explored in this study, such as teacher efficacy, years of teaching, professional development and prior work experience will be examined as either influences for traditional practice, predictors of reform teaching or variables of minimal significance. However, the focus of Chapter V is driven by the general themes which emerged through interviews and observations. As the RTOP scores suggest, classroom culture is the main predictor indicating where a teacher will land on the reform teaching spectrum. The emergent themes regarding the connection between teacher beliefs about learning, how these teachers view their roles and the rolls of their students', and how these beliefs materialize in the shaping of classroom culture, will be discussed in depth as predictors or barriers of reform education.

CHAPTER 5
ANALYSIS OF QUANTITATIVE AND QUALITATIVE DATA

The purpose of this mixed methods study was to explore predictors influencing teachers to choose reform practice as their primary method of teaching science classes. In conjunction with exploring predictors, this study also analyzed barriers that may influence teachers to continue using traditional methods. Also included is a discussion of the literature comparing the major findings of this research to current studies. An analysis is presented of the research data is supported by evidence gathered using quantitative instruments, observations and interviews. The subjects of this study are discussed as groups: Active Learning (Group One), Active Lecture (Group Two) and Traditional Lecture (Group 3). Group One is used as a comparison model for Group Two and Group Three. This data is used to answer the following research questions: (1) To what extent are biology teachers implementing reform based instructional practices in their classrooms, (2) What factors influence biology teachers to abandon reform education strategies and default to traditional methods of teaching, and (3) What factors predict whether a teacher will use reform strategies in their classroom?

Interpretation of the Findings

The research questions are addressed using the data collected through the employment of an explanatory sequential mixed methods design. Quantitative data identified the level of reform classroom instruction demonstrated by life science teachers who have experienced ten days of professional development grounded in the reform approach. Quantitative data also contributed to the identification of variables which functioned as predictors of reform instruction. Examples of quantitative research variables are; teacher self-efficacy and years of experience as compared to their Reform Teaching Observation Protocol (RTOP) rating. As per this research design, the researcher merged quantitative and qualitative data from observations and interviews. This data provided insight into teachers' beliefs regarding their perceived role in the classroom, their perspective of student learning using reform-based standards, and their understanding of the mechanics of a three-dimensional approach to learning. The researcher expanded this data exploring how teacher beliefs and skills are manifested in the classroom, particularly as it applies to classroom culture. Each theme will be discussed in the context of the research questions.

general question one

To what extent are biology teachers implementing reform based instructional practices in their classrooms?

The foundation of this study is based on identifying where teachers fall on the reform teaching spectrum. The RTOP is the instrument chosen by the researcher to measure the degree of reform mastery for each participant. The teachers were grouped into three categories based on their RTOP score. According to the RTOP guidelines, a score of 0-29 is classified as Traditional Lecture, 30-49 is Active Lecture, and 50+ is Active Learning, (https://serc.carleton.edu). This study is composed of 15 participants, five of these participants are identified as Active Learning, with an RTOP score ranging from 63-75.5, and will be referred to as Group One (G1). Five participants are identified as Active Lecture, with an RTOP score ranging from 33-45.5, and will be referred to as Group Two (G2). The remaining five participants are classified as Traditional Lecture with an RTOP score ranging from 9.5-28.5 and will be referred to as Group Three (G3). The RTOP validity and reliability data is found in Chapter Three.

A national database of the number of teachers using reform methods in their classrooms does not exist. Therefore, the researcher was unable to compare the practices of the participants in this study to a larger body of research. However, data from the National Assessment of Educational Progress (NAEP) indicated the trend towards reform methods of teaching science has increased from 2009 to 2015. The NAEP student questionnaire reported, "a higher percentage of eighth-grade students in 2015 had teachers who reported placing a *large* emphasis on developing systematic observation skills compared to 2009" (https://www.nationsreportcard.gov). Information from this same questionnaire also showed a ten percent increase in eighth-grade students responding that their teachers discussed the kinds of problems that engineers can solve more frequently. Two questions on the student questionnaire address reform pedagogy; the use of inquiry methods and connecting topics to engineering practices. These questions addressed pieces of a mastery reform program and are limitations of the NAEP data. A second limitation is that the process is dependent on the students' understanding of how inquiry learning, and engineering practices are defined. As the data is based on a questionnaire and does not include observations, it is unclear if the teachers were effectively implementing these practices to fidelity.

general question 2

What factors influence biology teachers to abandon reform education strategies and default to traditional methods of teaching?

The researcher examined several variables, using both quantitative and qualitative evidence, exploring why teachers choose traditional pedagogical methods even after participating in professional development grounded in reform practice. The research question is not applicable to G1 as this group scored in the Active Learning range of the RTOP instrument, indicating that they have demonstrated mastery of the reform approach. G1 is designated as a comparison model for the analysis of G2 and G3.

General Question Two is answered by examining the following descriptors; teacher self-efficacy, years of teaching, professional development background, prior work experience, highest degree earned and the RTOP categories of; Content Knowledge, Classroom Culture, and Lesson Design and Implementation. Each descriptor is addressed as a separate variable.

The Science Teaching Efficacy Belief Instrument for In-service Teachers (STEBI-A) is analyzed using the two subsets of Science Teaching Outcome Expectancy (STOE) and Personal Science Teaching Efficacy (PSTE). STOE is a teachers' belief that student learning is subject to influence by effective teaching. PSTE is defined as a teachers' perception about their own ability to effectively teach science (Sunal et al., 2019). This researcher analyzed the data using the z-score measurement for each group. The z-score for the PSTE and STOE was calculated and graphed according to a distribution curve (Diagram 3 and Diagram 4). The distance from the mean is interpreted as a comparison model of beliefs. Group Two ranked close to the mean for both subsets. G1, is described as having a PSTE below the mean and a STOE above the mean. In contrast, G3 charted a PSTE above the mean and a STOE below the mean. The significance is interpreted as G1 and G3 holding counter beliefs. Group One perceived their ability to teach science as less certain than G3, however they also believed that the quality of teaching can make a difference in student learning. Group Three perceived their ability to teach science as above average for this study, however they also believed that students are responsible for their own learning.

Bandura (1982) relates the degree of self-efficacy to the effort that a person is willing to put into learning a complex task and the behavioral changes that accompany changes in self-efficacy. This framework has been foundational for educational research particularly as it applies to pre-service and elementary school teachers (Bandura). However, the findings in the present study do not support the idea that a higher perception of PSTE translates into more effective reform teaching. The findings of Crippin (2008) more closely resemble the research conclusion and methodology of this study. Crippin measured the self-efficacy (SE) and outcome expectancy (OE) of 21 high school science teachers using the STEBI-A. Crippin reported that teachers with low SE and high OE (G1), used "receipt of knowledge", or tradition lecture less often than teachers with a high SE and low OE (G3). Although Crippin acknowledged the complexity of variables relating to pedagogical choices, he also concluded that traditional pedagogical teachers held a strong belief about the importance of their role as the holder of knowledge in the classroom (Crippen, 2008). The researcher concurs that beliefs influence pedagogical choices and offers further insight through interview and observation analysis in this chapter.

Years of teaching was measured as a possible variable affecting reform teaching. The RTOP score yields a value of r=.308. This weak correlation indicates no significant impact between years of teaching and utilizing reform classroom methods. A meta study of 30 research articles examined by the Learning Policy Institute (2016) reported that experience does contribute to a more effective teacher, however, this effectiveness peaks after a few years of teaching at which point the rate of effectiveness slows down. This literature is consistent with the present research findings. All teachers included in this study, except for one, have been teaching for three or more years.

The next variable, professional development and its impact on reform teaching, is explored using G1 as the comparison model. This comparison examined the differences in the degree of reform teaching as compared to G2 and G3. All the participants had completed a minimum of ten days of Alabama Science in Motion (ASIM) training. ASIM professional development is grounded in reform strategies consistent with the NGSS three dimensional (3D) standards. Teachers certified in ASIM training receive resources necessary to structure a reform-based classroom. These resources include all the materials necessary for structuring inquiry labs in addition to protocol written using the BSCS 5E Instructional Model (Bybee, 2006). On-site support throughout the school year is offered to any ASIM certified teacher upon request. In addition to ASIM training this researcher examined other types of professional development based on reform methods that may influence how teachers structure student learning. The comparison between G1 and G2 revealed that the participants in each group have similar professional development backgrounds. Both groups have four participants who attended the Hudson-Alpha Institute of Biotechnology (HAIB), a genetics-based training program which supplies labs and provides reform-based instruction. Group Three differs in that two of the teachers received ASIM combined with HAIB, two teachers participated in Alabama Math Science and Technology Initiative (AMSTI) professional development, and one teacher attended ASIM professional development only. The impact of professional development on reform practice, as it relates to this study, is unclear and cannot be classified as a barrier causing teachers to abandon reform practice. Although this researcher could not determine the effect of professional development on classroom practice, (Darling-Hammond, Hyler & Gardner, 2017) analyzed 35 rigorous studies and concluded a positive correlation between professional development, teacher practice and student outcomes. The criteria common to effective professional development is defined as; content focused, incorporates active learning, collaborative, using models and effective practice, provides coaching and support, provides feedback and reflection and is sustained in duration (Darling-Hammond et al., 2017). A 2009 report from the National Staff Development Council noted that while 90% of teachers said they participated in professional development training, most of them also said that the training was useless. This finding supports the idea that the quality of professional development supersedes the amount of time teachers spend participating in professional learning.

As several teachers in this study had careers prior to entering the teaching field, the researcher explored prior work experience as an influencing factor affecting pedagogical choices. Two participants in G1 had prior careers before entering the classroom, along with three teachers in G2, and two teachers in G3. Group One and G3 both included a participant who worked as a researcher prior to entering the teaching field. There is a current gap in research exploring the relationship between teaching science as a second career and adopting a reform pedagogical approach. The impact of second career teachers on RTOP performance cannot be determined using the parameters of this study.

The National Science and Engineering Indicators of 2016 report that teachers having a master's degree or higher have increased achievement among their high school students. For the purpose of a clear comparison, the researcher will only describe G1 and G3 data. Four of the teachers in G1 hold a Master's in Biology Education degree with one of the four having an Education Specialist Secondary Science degree. By contrast, G3 has three teachers holding a master's degree; two in General Science Education and one in Biology. Two of the five participants hold a bachelor's degree; one in Biology and one in General Science Education. This researcher has deemed the variable of educational background as inconclusive due to the small number of participants.

The three quantitative RTOP categories were analyzed independently as variables to determine which category revealed the largest disparity among the three groups. The Z-scores for each category are as follows:

- III. Lesson Design and Implementation (G1 = +.83, G2 = +.68, G3 = -1.1)
- IV. Content Knowledge (G1 = +1.2, G2 = -.17, G3 = -.76)
- V. Classroom Culture (G1 = +1.3, G2 = +.074, G3 = -1.1)

The coefficient variance was then calculated to determine which category revealed the largest disparity between the Z-scores, thus identifying the portion of the RTOP that had the greatest effect on the overall score. The coefficient variance value for each category is as follows: Content Knowledge (.435), Classroom Culture (.691) and Lesson Design and Implementation (.677).

Based on the coefficient variance, the categories of Classroom Culture and Lesson Design and Implementation show the largest point distribution among the three categories. Lesson Design and Implementation measures the teacher's ability to structure student activities that will promote divergent thinking and problem solving through active communication. Classroom Culture evaluates the type and frequency of interactions among students and between the students and teacher. Teachers proficient in reform-based teaching exhibit skills such as listening, exhibiting patience and acting as a resource. Further evidence of a reform classroom culture is a classroom environment with respectful and comfortable communication (Classroom Observation Project, 2020). This researcher identified classroom communication as informal, speaking without teacher permission or recognition, or formal, such as raising hands for recognition.

The last category, Content Knowledge, reveals the smallest dispersion among the three categories. This finding is consistent with the fact that all the participants have similar educational and professional development backgrounds. Content knowledge is eliminated as a variable in this study.

The evidence presented indicates that a teacher who is unskilled in classroom culture and reform-based lesson planning will have a higher chance of defaulting to traditional practice even after attending professional development based in reform methods. General Question Three identifies specific characteristics encompassing Lesson Design and Implementation and Classroom Culture. The exercise of narrowing these categories into more specific descriptors allows the researcher to present an in-depth analysis of the predictors. The elements described above play a dual role as predictor or barrier of reform education and are applicable to Question Three.

general question three

What factors predict whether a biology teacher will use reform strategies in their classrooms?

General Question Three used evidence collected through observations and interviews to support the identification of predictors of reform teaching. This question will be addressed by comparing the data between G1 and G3. Group Two will be discussed separately.

The data presented in General Question Two indicated two areas which had the most impact on reform classrooms; Lesson Design and Implementation and Classroom Culture. The researcher unpacked these two areas into more specific skill sets, based on observation and interview themes.

The RTOP category of Classroom Culture as:

- students ask question in an informal manner
- students generate questions driving class discussion
- teacher beliefs about their role as a facilitator
- teacher beliefs about student ability
- teacher beliefs about how students learn

The RTOP Lesson Design and Implementation skill subsets are identified as the following:

- teacher understanding of Three-Dimensional (3D) instruction
- students work effectively in groups

The analysis of each of these topics by comparing the teacher beliefs between G1 and G3 is described below. These beliefs were supported by observations and interview quotes for both groups.

Students ask question in an informal manner

The researcher observed that all the G1 students asked questions in an informal manner. An informal manner is described as students asking questions to each other or asking the teacher a question without raising their hands. Students are not required to be formally recognized before speaking. In contrast, G3 teachers had an expectation that their students would ask or answer questions by using the traditional method of hand raising. Talking out of turn was discouraged and sometimes punished. This method of encouraging students to ask each other questions is described by a G1 teacher, “A lot of times if I say things in a crazy way, they can talk to their partner and say, ‘this is how I understand it.” In contrast G3’s general method is summarized in the quote, “I talk about cells, I talk about levels of organizations…. I would also pull in bacteria and talk a little more about viruses”. Informal questioning is non-existent as the teacher is the only person talking in the classroom.

Students generate questions driving class discussion

The researcher observed that four of the five teachers in G1 encouraged students to generate questions driving class discussions. A representative G1 teacher describes encouraging class discussion as a method of formative assessment, “I like class discussion because I can tell a lot from a class discussion. But through class discussion I can tell,….do I need to stay on this another day.” In contrast, the researcher did not observe any teacher in G3 engaging student questions designed to drive class discussions. The quote, “They are still ninth graders and their maturity level is a little low and that leads to disruptive behavior…….” This is an indicator that these teachers generally do not trust their students to engage in productive questioning.

Teacher beliefs about their role as a facilitator

G1 and G3 teachers share different beliefs about their role in the classroom. Every teacher in G1 acted as a facilitator in contrast to G3 where none of the teachers were observed acting as facilitators. The observation of the teachers’ role in the classroom is supported by interview evidence. A representative quote for G1 is, “I have really strived to, especially in the last four years to remove myself and to make sure that the class is as student led as possible and that I’m truly the facilitator.” A teacher in G3 states, “I don’t know that giving them all that inquiry is good.” Group One embraced the role as a facilitator and promoted student interaction. Group Three teachers did not define their role in the classroom. Although G3 did not comment on how they view their relationship with students, several G1 teachers commented on the aspect of partnerships with students as a component of a positive classroom culture, supporting quotes include

- The teachers that were the best teachers were the ones who reached out to everybody.

- I think the first thing is to understand how to work with your student.
- ...we kind of just work together, like a partnership.
- You need to build a relationship with them so that they can feel comfortable with you even if they don't feel comfortable in school.

Comments from G1 teachers suggest that the cornerstone of a positive classroom culture begins with the teacher-student relationship.

Teacher beliefs about student ability

The participants in this study have differing beliefs about the ability of their students to participate in student-centered learning. Evidence of teacher views regarding student learning were revealed during the interview process. A representative quote from a G1 teacher states, "I like to have activities that allow them to explore without me giving them answers like ADI or investigations, critical thinking type activities where it doesn't require me talking…". All of the G3 teachers expressed concern about their students' ability to learn using 3D standards, "They're not ready for it. The students are not prepared for it, but I think it's a mistake to think that all students are ready for that type of rigor…"

Teacher beliefs about how students learn

The belief that students learn best through the methods of reform pedagogy is common to G1 teachers, "It's a process (learning). It's almost like re-learning, you see it one way and then you learn something else so then you have to re-evaluate what you've already learned." In contrast, a common belief for the G3 teachers is exemplified by the quote, "To be honest rote has been the best job with these guys."

The elements of Lesson Plan and Implementation are analyzed using the following three subcategories; Teacher understanding of 3D instruction, Students working effectively in groups and students actively exploring phenomena.

Teacher understanding of Three-Dimensional (3D) instruction

Group One teachers expressed an understanding of how and why the 3D standards are important to student learning, “We were kind of uncomfortable with it (2015 ACOS) at first but pretty much it just took a restructuring of what we were already doing…. like with the alkaptonuria lab it took just removing the inheritance pattern from the beginning changed the lab to make it more inquiry based.” “It (lab activities) makes kids plan, and it also makes them think. When things don’t work, you always have to figure something out.” Group Three teachers harbor misconceptions about the conceptual nature of the 3D standards, “It’s a combination of experiences and a told set of things--that plus the effort of trying to learn something.” “I try to reach all the kids by doing some type of activity every day.” “The only labs that I do are something like a quick intro lab that’s like a demonstration.” Group Three teachers were observed having an incomplete understanding of the mechanics of 3D instruction, including the role of scaffolding, using models and exploration. In addition, data on teacher beliefs, obtained from interviews, indicate that these teachers do not value 3D learning, based on reform methods, as a viable pedagogical choice. This was indicated and represented by the following quote, “I can’t give them everything. I think if we just went back to the old way of teaching, you know if you got it, you passed the test……” This evidence suggests that teachers not only undervalue the process of teaching the 3D standards, they also hold misconceptions about the nature of reform methods.

Students work effectively in groups

The mechanics of reform education requires students to work effectively in groups. Group work is a cornerstone of student-centered instruction. All the students in G1 effectively participated in group work. As a G1 teacher stated, "I'm coming in to give you directions and guidance but I'm never coming in to give you the answer." G1 teachers effectively enact the mechanics of group work with a clear understanding that peer discussion is a valuable part of student learning. In contrast, the G3 students did not, at any time, engage in group activity. The only mention of student dialog is framed as a disturbance to learning and contributing to a discordant classroom culture as exemplified in the quote, "while you are trying to talk about something and the person that is being disruptive is talking, yelling, throwing pencils and getting up and moving around the class, kids cannot focus."

Group Three shares a belief that inquiry methods associated with reform education are ineffective and that traditional lecture is the best way to provide students with knowledge. This group also universally shares a belief that not all students can learn using 3D standards as they are too rigorous, and the students are not prepared. The belief that reform methods lack value is a predictor that these teachers will default to traditional lecture even after reform based professional development.

The differing beliefs between G1 and G3 participants is supported by the Personal Science Teaching Efficacy (PSTE) data. G1 teachers averaged below the mean on the PSTE distribution curve. The interview evidence indicates that this group of teachers are aware of their own practice and believe that they can continue to improve their craft. As a G1 teacher stated, "It's been a struggle but that's my approach." Group Three averaged above the mean. Indicating that these participants held the belief that their method of teaching science is the best approach for student learning. Interview evidence supported this belief. A G3 teacher described a non-lecture approach as, "The habit of education is always keeping them entertained." Science Teaching Outcome Expectancy (STOE) data also supports the differing beliefs between the two groups. Group One teachers averaged above the STOE indicating that they believe effective teaching can influence student learning, "I have to tell myself every day, it's worth it. It matters; the outcome is worth it." Group Three teachers, averaging below the STOE mean, held the belief that students are responsible for their own learning, "…you know, if you got it, you passed the test and did the work then rigor, if you were allowed to fail a student, you know just let them fail that's enough incentive for you to do something…" The evidence indicates that G1 and G3 teachers hold differing beliefs in every subset category for Lesson Design and Implementation and Classroom Culture.

Group Two shares practices and beliefs of both G1 and G3. The RTOP identified this group as Active Lecture. The analysis for G2 is organized by subset and identified as sharing beliefs with either G1 or G3.

Students ask question in an informal manner

The most often used method of student questions were presented in an informal manner. Group Two's practice of this subset is more closely aligned with G1 teachers.

Students generate questions driving class discussion

One of the five teachers was observed as using student questions to drive class discussion. This practice was not observed for the remaining teachers in this group. This data is reflective of G3's practice.

Teacher beliefs about their role as a facilitator

Two of the five teachers were observed practicing the role as a facilitator for a small portion of the class time. The near absence of this skill more closely aligned with the practices of G3. Interview evidence did not reveal a common belief regarding the teachers' role in the classroom or their relationship with students. The available evidence was insufficient to assign a comparison group.

Teacher beliefs about student ability

One G2 teacher referenced frustration with student ability, "The difference in teaching levels is very, very large and so I feel like I could be doing a lot more if I had a class where I didn't feel like I was baby-sitting or crowd control." The remaining four teachers did not mention their students' ability to learn using reform methods during the interviews. The available evidence was insufficient to assign a comparison group.

Teacher beliefs about how students learn

Two of the five teachers responded to interview questions about student learning. The response indicated that these teachers believed students learn best through non-traditional methods, "…you've got to have evidence to back it up, you can't just make no sense whatsoever and be rude." "If you can connect it with something in their memory, then they can access it real quick." The available evidence was insufficient to assign a comparison group.

Understanding three-dimensional instruction

This researcher analyzed interview responses to determine if the G2 participants held misconceptions about 3D learning. Three of the five teachers referred to a specific non-lecture-based model of teaching; flipped classroom, 5E Model, and 3D instruction. Representative quotes are, "I try to follow the 5E Model, the engage that gets their attention and I really like inquiry." "I believe that if the teacher makes learning three dimensional, they present the material to all different types of learning." The researcher determined that these teachers understood the mechanics of 3D instruction. Two of the five teachers expressed discomfort teaching 3D instruction, "They (3D Standards of the 2015 ACOS) are deep and take a ton of planning and a lot of resources." " I just don't feel like I have the time and I struggle with how deep I'm supposed to go." Although the G2 teachers expressed a belief that the reform approach is valuable to student learning, the researcher observed the practice of these teachers as defaulting to a predominantly lecture format. Group Two shared beliefs like the G1 teachers matched their practice, however, their practice did not reflect the same level of pedagogical skill. Unlike the G3 teachers, who expressed a preference for traditional teaching, the G2 teachers valued reform-based education, although their practice remained predominantly traditional lecture reflective of G3.

Students work effectively in groups

All the students in the G2 classrooms were observed working effectively in groups during a portion of the class. Unlike the G1 teachers, the G2 participants did not discuss the value of group work or student discourse that drives student learning during group exercises. The observation of G2 group work was more reflective of an "activity" rather than a foundational method of student learning.

Summary

General Question One: To what extent are biology teachers implementing reform based instructional practices in their classrooms? Quantitative data based on the RTOP guidelines indicate that of the 15 participants, five teachers are practicing Active Learning, five teachers are practicing Active Lecture and five teachers are categorized as Traditional Lecture.

General Question Two: (What factors influence teachers to abandon reform education strategies and default to traditional methods of teaching?) and General Question Three: (What are the factors that predict if a teacher will use reform strategies in their classrooms?), have a dual role. The data are viewed as both a factor that influences teachers to default to traditional methods and as a predictor that teachers will use reform methods in their classrooms.

Group One teachers held the belief that student learning can be influenced by effective teaching as indicated by STOE. The belief that student learning is influenced by quality instruction is a predictor of reform pedagogy. Sannino described the ability to shift practice as transformative agency, “Transformative agency is a quality of expansive learning. Learning expansively requires breaking away from the given frame of action and taking the initiative to transform it. The new concepts and practices generated in an expansive learning process carry future-oriented visions loaded with initiative and commitment by the learners” (Sannino et.al, 2016). Group One teachers view their role in the classroom as a facilitator and view their relationship with students as a partnership. These teachers demonstrated an understanding of constructing a classroom culture through student-student discourse and teacher-student discourse. Group One teachers believed that students learn best through experience and peer dialog. Teachers who share this belief are observed practicing reform methods. Teachers who do not hold these beliefs are observed practicing traditional pedagogy (Bandura, 1982). Based on G1 data, predictors of reform pedagogy are positive beliefs about quality instruction and student outcome, positive beliefs about the efficacy of reform pedagogy, and understanding of 3D instruction. In addition to beliefs other predictors are skills associated with forming student relationships, organizing groups and facilitating student discourse.

The researcher summarized that teachers who do not share a belief in the process of reform teaching and have not mastered the skills associated with a student-centered classroom culture, will continue to default to traditional practice.

As indicated by the evidence affiliated with G2, a shared belief alone is not a certainty of reform-based classroom practice. The role of teacher beliefs must be accompanied by reform-based skills in order to achieve transformative agency. Group Two embraced the beliefs of reform practice but lacked the pedagogical skills affiliated with classroom culture. An observation of their classrooms appeared to be predominately traditional lecture.

The researcher will discuss the implications of these findings in the context of professional development in Chapter Six.

CHAPTER 6
SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

In the previous two chapters, the researcher analyzed and merged the data in accordance with the mixed methods Explanatory Sequential Design (Ivankova, Creswell & Stick, 2006). This chapter is a discussion of the research findings, relating these findings to prior research and recognizing the limitations. The implications of this study examined factors related to the preparedness of teachers to enact reform-based instructional models. The conclusion will introduce hypotheses generated by the study and recommend further research pertaining to the Pedagogical Content Knowledge (PCK) needed to effectively construct a reform-based classroom.

Study Summary

The initial goal of this exploratory study was to identify specific characteristics teachers need to successfully conduct reform teaching in science classrooms. This goal was approached by examining barriers and predictors of reform practice among groups of teachers who previously participated in professional development grounded in reform methods. The following research questions were based on the goals of the study.

1. To what extent are biology teachers implementing reform based instructional practices in their classrooms?
2. What factors influence biology teachers to abandon reform education strategies and default to traditional methods of teaching?

3. What factors predict whether a biology teacher will use reform strategies in their classroom.

The researcher chose the Explanatory Sequential Design (Ivankova, Creswell & Stick, 2006) as a method of effectively merging quantitative data gathered from the Reform Teaching Observation Protocol (RTOP) and the Science Teaching Efficacy Belief Instrument for In-service Teachers (STEBI-A), with qualitative evidence collected through classroom observations and interviews. This merger identified certain variables that may influence a teacher's pedagogical choice.

By selecting teachers who have attended 10 days of Alabama Science in Motion (ASIM) professional development, the researcher could compare teachers who had a common professional development experience using reform methods. Alabama Science in Motion professional development presents content deepening and pedagogical training aligned with the BSCS 5E Instructional Model (Bybee, 2014). The ASIM training component is described as follows, "ASIM also incorporates a strong teacher-training component. Each site provides 8 days of teacher training. Summer training is designed to update and strengthen content knowledge, to familiarize teachers with the use and operation of ASIM equipment, and to model teaching strategies that are successful with a broad range of students", (University of Montevallo, nd). ASIM provides lab protocol formatted in accordance with the BSCS 5E Instructional Model for each standard. Alabama Science in Motion certified teachers have access to supporting resources, thus eliminating a lack of materials as a variable.

The selection process was initially designed using a fishbowl random selection method. Due to lack of response, three of the fifteen teachers were chosen using the snowball method, teachers referring other teachers. After completion of the selection process, and in accordance with the mixed methods design described in Chapter 3, this researcher collected quantitative and qualitative evidence related to the research questions. The process of evidence collection initiated with the teacher completing the Likert scale formatted STEBI-A instrument (Riggs & Enochs,1990) before the observation process. The STEBI-A results were analyzed using the subcategory scores of Personal Science Teacher Efficacy (PSTE) and Student Outcomes Effectiveness (STOE). The researcher then observed each teacher for two consecutive class periods using the RTOP protocol. The RTOP instrument is designed specifically to measure the degree of reform methods used in classrooms (Pilburn et al., 2000). Part I of the RTOP instrument is designated for background data such as date, location, years of teaching and teacher certification. Part II of the RTOP is a description of the class setting including demographic information about the student body. Parts III – V are quantitative measures, using a Likert scale for identifying the degree to which teachers are observed using reform methods in their classroom. Each quantitative section identifies unique characteristics of a reform classroom; part III (Lesson Design and Implementation), part IV (Content) and part V (Classroom Culture). The researcher used the quantitative data provided from this instrument to determine the category of the 15 participants in accordance with the RTOP recommendations. These categories are Active Learning, Active Lecture and Traditional Lecture (Classroom Observation Project, nd). The data collection process concluded with an interview conducted after the final observation.

The data analysis concluded that teachers designated as Active Lecture share beliefs about reform education with the Active Learning group, however, they lack the Pedagogical Content Knowledge (PCK) necessary to construct a reform classroom culture; thus, defaulting to methods more closely related to the Traditional Lecture group.

Relating Findings to Research Literature

Research question 1: To what extent are biology teachers implementing reform based instructional practices in their classrooms?

This researcher analyzed the data gathered from the RTOP and placed the participants in predetermined categories. The RTOP identified these categories as Active Learning, Active Lecture and Traditional Lecture. The outcome indicated that five of the fifteen participants were in the Active Learning group and used reform methods as their primary approach to student learning. Five of the fifteen teachers implemented periodic elements of reform teaching and were identified as Active Lecture. The remaining five teachers were categorized as Traditional Lecture.

The National Science Foundation defines reform as, "moving from a focus on textbooks and disconnected facts toward direct and coherent exploration of science concepts through active student learning" (Cozzens, 1997, p. vii). The concept of reform practice is well documented as the most effective approach towards developing a student's understanding of the practice of science (Bybee, Taylor, Gardner, et al., 2006; Shulman, 1987; Sunal, 2006; Heflebower, Hoegh, Warrick, et al., 2019). A study based on the 2018 data, collected by the National Survey of Science and Mathematics Education (NSSME), surveyed 1,038 high school science teachers from across the United States and reported that fewer than half of these teachers emphasized learning the practice of science as the primary goal for student outcome. The study concluded science students are not asked to critically analyze evidence on a regular basis, "These data are particularly interesting as, despite the fact that nearly all teachers believe students learn science best by doing science, fewer teachers have students learning to do science as an instructional goal or are engaging students in the science practices during instruction", (Bandilower et al., 2018). The study conducted by this researcher is supported by the NSSME study, both concluding that less than half of the science teachers effectively implemented reform teaching.

Research Question 2: What factors influence biology teachers to abandon reform education strategies and default to traditional methods of teaching?

Interview evidence collected by the researcher indicated the Traditional Lecture group (G3), held a belief that the rigor of reform methods, as modeled through ASIM professional development, was beyond the capability of their students. This group also held a belief that effective teaching had little impact on student learning as indicated by the Science Teaching Outcome Expectancy (STOE) results. The researcher observed the elements of PCK required to cultivate a reform-based classroom culture as minimal for the Active Lecture group (G2) absent in Tradition Lecture Group (G3).

The results of a 2017 study identified several barriers preventing teachers from using the reform-based methods of the Next Generation Science Standards (NGSS). The relevant results indicated teachers were unsure if their students could handle the rigor embedded in the NGSS standards. These results also cited teacher's lack of knowledge regarding the PCK required to implement the engineering practices of the NGSS (Shernoff, Ruzek & Sinha, 2016). The Indiana Science Initiative (ISI) published similar findings. The ISI surveyed 157 K-12 science teachers using a paired STEBI-A pre-test and post-test data set. The pre-test was administered prior to a two-year professional development initiative grounded in guided inquiry methods. The first-year paired data showed an increase in Personal Science Teaching Efficacy (PSTE) and a decrease in Science Teaching Outcome Expectancy (STOE). The second-year post-data indicated that there was an increase in both PSTE and STOE scores. The researcher hypothesized that as teachers improve PCK they become more confident in their ability to influence student learning.

The Shernoff (2016) study supports the findings found by this researcher regarding the teachers' perception of his or her student's ability to master the rigor of reform methods. The first year ISI data is reflective of the STOE data analyzed by this researcher, indicating that teachers who practice traditional methods have a lower STOE score than their counterparts who engage in reform teaching. An important difference between the ISI study and this research is that ISI did not report observed reform practice after professional development intervention. The ISI hypothesized that beliefs are influenced by PCK whereas this researcher, through observations, identified beliefs as a predictor for improving PCK. As stated by Yerrick, "Overall we found that teachers fit new messages into their overall beliefs. We predict that if and when conflicts arise in their expectations for and with students, they will return to their practices that have worked for them in the past" (Yerrick, 1998, p. 154).

Research Question 3: What predicts whether biology teachers will use reform strategies in their classroom?

The Active Learning group (G1) effectively implemented reform methods in their classrooms. This group was used as a model to identify predictors associated with effective reform teaching. The STOE score for G1 indicated that these teachers believed teaching practices impact student learning. This belief is identified as a predictor of reform classroom practice. Other predictors were identified as embedded themes found in observations and interviews. The researcher identified the following elements PCK as wholly present in G1 (Active Learning), partially present in G2 (Active Lecture) and absent in G3 (Traditional Lecture).

- students asking questions in an informal manner
- students work effectively in groups

- teacher acting as a facilitator
- students generate questions driving class discussion

The commonality among these predictors is the PCK required to create an environment effectively promoting student cooperation and collaboration through listening, questioning and student discourse. Facilitator efficacy for the G1 teachers was observed as the driving PCK which sustained the student-centered environment. Interview evidence supported these observations. Research and models connecting experiences to understanding abstract scientific phenomenon is common in reform literature (*How People Learn,* 2000; Bybee, 2012; CEPNi, 2012; Keeley, 2008; Posner, 1982). Several reform-based models provide a framework for outlining the general components of reform instruction which include student interaction (Bybee, 2012; Strike & Posner, 2007). The limitations of these models are that they do not address the PCK teachers need to construct a reform classroom grounded in student experiences. An example of a current reform-based model is Marzano's (2017) *The New Art and Science of Teaching.* Marzano constructed an approach for organizing students to interact using some of the following strategies:

- Structured grouping
- Plan to ungroup students
- Cooperative learning
- Peer response
- Peer tutoring (Marazano, 2017, p. 62)

Marzano's (2017) reform model represents the assumption that teachers intuitively understand how to incorporate the recommended strategies. The same theme of student-centered learning is also emphasized as foundational in the NGSS handbook, "Teachers need to build a classroom culture that can support these practices, where students are motivated to figure out rather than learning what they are told, where they expect some responsibility for this work of figuring out rather than waiting for answers, and where they expect to work with and learn with their peers" (Reiser, 2013, p.11). These examples place the teacher in the role as a facilitator which requires PCK grounded in promoting student collaboration and cooperation. The evidence provided by this study challenges the assumption that all teachers are prepared to step into the role of a facilitator who can create a student-centered classroom rich in student discourse.

Implications

The main implication of this study is the identification of a particular type of pedagogical knowledge that was observed in the Active Learning group and absent in the Traditional Lecture group. The term Pedagogical Content Knowledge (PCK) was coined by Lee Schuman (1987) to describe the specialized knowledge that fuses subject matter with the most appropriate method of instruction. For the purpose of this discussion the researcher will refer to the following findings as Pedagogical Knowledge (PK).

The particular type of PK observed in this study is the ability of the Active Learning teachers to coalesce their students into a learning community that was collaborative and rich in student discourse. This researcher refers to this unique quality as Facilitator PK. Facilitator PK is represented by the following observations:

- causal content related student discourse, in groups or as a whole class discussion
- students asking other students for clarification
- students communicating with the teacher in an informal manner
- Teacher acting as learning partner
- No protocol for being recognized before speaking

Facilitator PK is identified as a possible unique component of PCK required to implement reform-based classroom practices.

Hypotheses Generated by the Study

Hypothesis #1: Changing teacher's beliefs regarding their perceived impact on student learning will influence their classroom practice.

The participants in this study were observed implementing varying degrees of reform classroom practice. Teachers who demonstrated fidelity to the reform model also strongly believed that their instruction influenced student learning outcomes. Teachers who demonstrated traditional lecture methods expressed their preference for this approach through observations and interviews. The STEBI results indicated the Traditional Lecture teachers did not believe they could influence student outcomes. Although it is difficult to change teachers' practices which are at odds with their own beliefs (Olson, 1981), beliefs interact with practice rather than define them (Richardson, 1996). The limitations of the evidence from this researcher's study are the small number of participants in addition to interview questions that were not designed to examine specific pedagogical beliefs or justification of practice.

The question, "Do beliefs in student outcome influence practice or does practice influence beliefs about student learning?" is the foundation of the first hypothesis: Changing teachers' beliefs regarding their perceived impact on student learning will influence their classroom practice. Research methods exploring this hypothesis would be designed as a mixed method, professional development intervention, grounded in constructivists theory. The proposed data sources are, reform-based quantitative instruments, student outcome belief instruments, and interviews. Those teachers who are identified as Traditional Lecture teachers would be the target group. The pre-professional development interview would be designed to generate teacher reflection and justification of their current pedagogical practice. Pre and post data from The Science Teaching Efficacy Belief Instrument (STEBI-A) is a possible source of alignment with interview themes. The professional development intervention would be designed in two phases; 1) Teachers would partner with a research cohort and engage in authentic research experience. A defining characteristic of this research cohort would include sustained social interaction. This experience would represent learning as a student. 2) Teachers would attend a post-research session(s) with the goals of reflecting on their own learning outcomes and connecting their experience with classroom practice grounded in the NGSS standards. Post instrument surveys and follow up observations would provide effect size data. Post interview data could provide evidence of changing teacher beliefs.

Hypothesis #2 Professional development focusing on the PCK associated with the role of a facilitator can maximize the success of teachers as they shift to student-centered approaches.

An observed theme of the Active Learning group was their ability to demonstrate the role of a proficient facilitator. A limitation of this observation was that this researcher did not carefully focus on identifying a pattern of common traits affiliated with effective facilitators. In addition, interview questions were not designed to explore the role of facilitator in reform teaching. A third limitation is the small number of teachers that were observed. Professional development programs often focus on what teachers need to do rather than questioning what teachers are ready to do. Moving towards reform-based instruction could have a personal impact on the teacher. Assuming the role of a facilitator will require many teachers to change their identity in order to structure a reform classroom (Keiler, 2018). A current study suggests radically changing the learning environment can affect teachers' identities in STEM classrooms.

This shift can affect teachers by either aligning with their own identity as a facilitator or creating an environment that is at odds with their identity (Keiler, 2018).

Adapting to the role of a classroom facilitator leads to the second hypothesis: Professional development focusing on the PCK associated with the role of a facilitator can maximize the success of teachers as they shift to student-centered approaches. Identity is an ongoing process of interpretation and re-interpretation of experiences (Beijaard et al., 2004). Research on shifting teacher identity would be designed as an intervention-based professional development. This intervention would include professional learning, embedded classroom modeling and ongoing support, grounded in developing an identity as a facilitator. Formal professional learning aligned with facilitator PCK center on the topics of; designing a classroom that promotes student discourse, managing student-centered groups and incorporating student driven questions. This professional development would be directed at teachers with shared reform-based beliefs and weak reform-based implementation skills as demonstrated by the Active Lecture group. The logistics of this research would require a small sample number. Elements of effective facilitation would be quantitatively analyzed with periodic RTOP data throughout the school year. Periodic interviews would document changes in identity that the teacher may be experiencing. Student work would be analyzed for greater learning outcomes as one measure of teacher success.

Hypothesis #3 Multi-year professional development grounded in content specific reform instruction will increase reform practice for teachers who have a shared belief in the reform approach but continue to teach using traditional methods.

Interview evidence indicated the Active Lecture group shared a belief with the Active Learning group. Both groups believed that reform methods are the best approach for teaching science. However, observations revealed that the Active Lecture groups' practice is at odds with their belief. Teachers who claim to embrace reform beliefs but continue to practice traditional lecture is a phenomenon that has been observed in previous research (Savasci & Berlin, 2012, Veal et al. (2016). This phenomenon leads to the third hypothesis: Multi-year professional development grounded in content specific reform instruction will increase reform practice for teachers who have a shared belief in the reform approach but continue to teach using traditional methods. The Alliance for Physics Excellence (APEX) designed a three-year study of physics content-focused professional development grounded in reform teaching. The study concluded that multi-year, reform based professional development resulted in an increased occurrence of reform-based instructional practice (Ogodo, 2019). Using the same research methods and instruments (RTOP, STEBI, field notes and interviews) as in the APEX study and this study, the research would target Active Lecture biology teachers across the state. Justification for focusing on Active Lecture teachers is based on effort and return of investment. If teachers believe in the outcome, they are more likely to proceed through the difficult process of changing their practice in order to achieve their goal, (Crawford, 2007).

Exploratory Research Question: What interpersonal characteristics are observed by science teachers who proficiently facilitate student discourse?

The researcher observed that the Active Learning group and the Active Lecture group personally interacted with their students differently than the Traditional Lecture group. The Traditional Lecture group communicated with their students in a traditional manner exemplified by hand raising prior to recognition and authoritative discourse. This behavior was not observed in the other two groups; rather, classroom discussions and student questions were observed to arise without a set protocol for discourse. The researchers' observation could indicate that a unique type of PCK may be involved with facilitating student discourse as a foundation of classroom culture. The weakness of this observation was that the researcher identified this trend during the analysis phase and did not closely observe classes with the goal of identifying patterns of discourse. A second limitation was that the interview questions did include a discussion asking teachers to justify their approach towards classroom discourse. A third limitation was the small number of participants included in the study.

Research studies indicate communication is foundational to constructing a reform classroom (Anderson, 2002; Bybee, 2004; Hogan, 1999). Observing a possible pattern of personal interactions between teachers who use reform methods and student discourse, generated an exploratory research question: What interpersonal characteristics are observed in science teachers who proficiently facilitate student discourse? This research would encompass a statistically reliable subject base and continue with the methods of classifying teachers according to their degree of reform instruction. Observation evidence would compare interpersonal interactions between Active Learning and Traditional Lecture groups. Interview questions would be designed to engage teacher discussion regarding their interpersonal relationship with their students and justification of their methods.

As states, systems and schools continue to move forward with three-dimensional standards grounded in reform-based science teaching, a supportive professional development network will ease the rough-and-tumble aspects of this transition. Rather than a one-size-fits-all approach, professional development should be tailored to the needs of teachers, whether it is changing beliefs about reform methods, identifying as a facilitator, developing the elements of PCK required to create a reform-based classroom, or enhancing classroom communication.

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Appendix A: Influential Research

Author	Study Title	Variables	Instruments	Research Features	Conclusion
Acisli, Yalcin and Turgut 2011	Effects of the 5E Learning Model on Students' Academic Achievements in Movement and Force Issues	Control group – did not receive instruction using the 5E Instructional Model	Pre-test Post-test T-test analysis	The 5E model is more successful than traditional instruction Institutional Recommendation that all pre-service teachers receive training using the 5E Instructional Model	Examining the academic value of using the 5E Instructional Model
Kuchey, Morrison and Geer 2009	A Professional Development Model for Math and Science Educators in Catholic Elementary Schools: Challenges and Successes	Treatment group – received instruction using the 5E Instructional Model	Pre-test and post-test measuring content knowledge Evaluation of lesson plans for inquiry practice Science Teacher Efficacy Belief Instrument (STEBI)	Increase in the application of inquiry pedagogy Gains in student achievement Increase in teacher self-efficacy	Common research topics of the constructivist learning theory, teaching the national standards using the learning cycle and the effects of professional development on teacher self-efficacy
Slavkin, M. 2014	Indiana Science Initiative Update: An Analysis of the Integrating Science,	Qualitative study analyzing teacher surveys	Teacher surveys about curriculum and instruction	Science teachers believe that it is important to teach the NGSS however few of them feel prepared to	This study highlights the uncertainty that teachers face as they attempt to incorporate

	Engineering and Mathematics to Improve Student Learning			teach the three dimensions. They are particularly uncomfortable teaching the SEP's	the 3 Dimensions of the NGSS as a national issue
Haag & Megowan 2015	Next Generation Science Standards: A National Mixed-Methods Study on Teacher Readiness	Control group- did not received professional development based on the Modeling Instruction Program Treatment group- received instruction using the Modeling Instruction Program	Survey of teacher preparedness based on a five-point Likert scale and analyzed using ANOVA Open ended questions coded for emerging themes	The treatment group felt more motivated to use the NGSS SEP's in their classrooms as compared to the teachers who did not receive instruction. The NGSS SEP's were identified as a high needs area for professional development.	Identifies professional development needs as teachers shift their classrooms to a conceptual model

Appendix B: Reformed Teaching Observation Protocol (RTOP)

I. Background Information

Name of Teacher: ________________________________ Announced
Observation:______________

(yes or no)
Location of class:____ *(district, school, room)*
Years of Teaching:________________ Teaching Certification _________________
Subject observed:________________ Grade level:_______________
Observer____
Date of Observation: ________________________
Start time:________________ End time:____________________

II. Contextual Background and Activities

In the space provided below please give a brief description of the lesson observed, the classroom setting in which the lesson took place (space, seating arrangements, etc.) and any relevant details about the students (number, gender, ethnicity) and teacher that you think are important. Use diagrams if they seem appropriate

III. Lesson Plan & Implementation

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

IV. Content

Propositional knowledge		never occurred very descriptive
	6.) The lesson involved fundamental concepts of the subject	0 1 2 3 4
	7.) The lesson promoted strongly coherent conceptual understanding.	0 1 2 3 4
	8.) The teacher had a solid grasp of the subject matter content inherent in the lesson.	0 1 2 3 4
	9.) Elements of abstraction (i.e., symbolic representations, theory building) were encouraged where it was important to do so.	0 1 2 3 4
Procedural Knowledge	10.) Connections with other content disciplines and/ or real world phenomena were explored and valued.	0 1 2 3 4

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

V. Classroom Culture

Communicative Indicators		never occurred very descriptive
	16.) Students were involved in the communication of their ideas to others using a variety of means and media.	0 1 2 3 4
	17.) The teacher's questions triggered divergent modes of thinking.	0 1 2 3 4
	18.) There was a high proportion of student talk and a significant amount of it occurred between and among students.	0 1 2 3 4
	19.) Student questions and comments often determined the focus and direction of classroom discourse.	0 1 2 3 4

	20.) There was a climate of respect for what others had to say.	0 1 2 3 4
Student/Teacher Relationships	21.) Active participation of students was encouraged and valued.	0 1 2 3 4
	22.) Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	0 1 2 3 4
	23.) In general the teacher was patient with students.	0 1 2 3 4
	24. The teacher acted as a resource person, working to support and enhance student investigations.	0 1 2 3 4
	25.) The metaphor “teacher as listener” was very characteristic of this classroom.	0 1 2 3 4

Additional comments about this lesson

Appendix C: Reform Teaching Observation Training Guide (RTOP)

The Reformed Teaching Observation Protocol (RTOP) is an observational instrument that can be used to assess the degree to which mathematics or science instruction is "reformed." It embodies the recommendations and standards for the teaching of mathematics and science that have been promulgated by professional societies of mathematicians, scientists and educators. The RTOP was designed, piloted and validated by the Evaluation Facilitation Group of the Arizona Collaborative for Excellence in the Preparation of Teachers. Those most involved in that effort were Daiyo Sawada (External Evaluator), Michael Piburn (Internal Evaluator), Bryce Bartley and Russell Benford (Biology), Apple Bloom and Matt Isom (Mathematics), Kathleen Falconer (Physics), Eugene Judson (Beginning Teacher Evaluation), and Jeff Turley (Field Experiences).

The instrument draws on the following sources: • National Council for the Teaching of Mathematics. Curriculum and Evaluation Standards (1989), Professional Teaching Standards (1991), and Assessment Standards (1995).

• National Academy of Science, National Research Council. National Science Education Standards (1995).

• American Association for the Advancement of Science, Project 2061. Science for All Americans (1990), Benchmarks for Scientific Literacy (1993).

It also reflects the ideas of all ACEPT Co-Principal Investigators, but especially those of Marilyn Carlson and Anton Lawson, and the principles of reform underlying the ACEPT project. Its structure reflects some elements of the Local Systemic Change Revised Classroom Observation Protocol, by Horizon Research (1997-98).

The RTOP is criterion-referenced, and observers' judgments should not reflect a comparison with any other instructional setting than the one being evaluated. It can be used at all levels, from primary school through university. The instrument contains twenty-five items, with each rated on a scale from zero (0) (not observed) to four (4) (very descriptive). Possible scores range from zero (0) to 100 points, with higher scores reflecting a greater degree of reform.

The RTOP was designed to be used by trained observers. This Training Guide provides specific information pertinent to the interpretation of individual items in the protocol. It is intended to be used as part of a formal training program in which trainees observe actual classrooms or videotapes of classrooms and discuss their observations with others. The Guide, in its present form, is also designed to solicit trainee thoughts and concerns so that they feel comfortable in using the instrument. For that reason, a space is provided after each item for trainee comments. Such input helps all those being trained to achieve a higher degree of consistency in using the instrument. Please keep this in mind in making comments. March 2000 Revision 1 Copyright ©

I. BACKGROUND INFORMATION: This section contains space for standard information that should be recorded by all observers. It will serve to identify the classroom, the instructor, the lesson observed, the observer, and the duration of the observation.

II. CONTEXTUAL BACKGROUND AND ACTIVITIES: Space is provided for a brief description of the lesson observed, the setting in which the lesson took place (space, seating arrangements, etc.), and any relevant details about the students (number, gender, ethnicity, etc.) and instructor. Try to go beyond a simple description. Capture, if you can, the defining characteristics of this situation that you believe provide the most important context for understanding what you will describe in greater detail in later sections. Use diagrams if they seem appropriate.

The next three sections contain the items to be rated. Do not feel that you have to complete them during the actual observation period. Space is provided on the facing page of every set of evaluations for you to make notes while observing. Immediately after the lesson, draw upon your notes and complete the ratings. For most items, a valid judgment can be rendered only after observing the entire lesson. The whole lesson provides contextual reference for rating each item. Each of the items is to be rated on a scale ranging from zero (0) to four (4). Choose "0" if in your judgment, the characteristic never occurred in the lesson, not even once. If it did occur, even if only once, "1" or higher should be chosen. Choose "4" only if the item was very descriptive of the lesson you observed. Intermediate ratings do not reflect the number of times an item occurred, but rather the degree to which that item was characteristic of the lesson observed. The remainder of this Training Guide attempts to provide a clarification of each RTOP item and the subtest (there are five) of which it is a part.

III. LESSON DESIGN AND IMPLEMENTATION:

1) The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein. A cornerstone of reformed teaching is taking into consideration the prior knowledge that students bring with them. The term "respected" is pivotal in this item. It suggests an attitude of curiosity on the teacher's part, an active solicitation of student ideas, and an understanding that much of what a student brings to the mathematics or science classroom is strongly shaped and conditioned by their everyday experiences.

2) The lesson was designed to engage students as members of a learning community. Much knowledge is socially constructed. The setting within which this occurs has been called a "learning community." The use of the term community in the phrase "the scientific community" (a "self-governing" body) is similar to the way it is intended in this item. Students participate

actively, their participation is integral to the actions of the community, and knowledge is negotiated within the community. It is important to remember that a group of learners does not necessarily constitute a "learning community."

3) In this lesson, student exploration preceded formal presentation. Reformed teaching allows students to build complex abstract knowledge from simpler, more concrete experience. This suggests that any formal presentation of content should be preceded by student exploration. This does not imply the converse...that all exploration should be followed by a formal presentation.

4) This lesson encouraged students to seek and value alternative modes of investigation or of problem solving. Divergent thinking is an important part of mathematical and scientific reasoning. A lesson that meets this criterion would not insist on only one method of experimentation or one approach to solving a problem. A teacher who valued alternative modes of thinking would respect and actively solicit a variety of approaches and understand that there may be more than one answer to a question.

5) The focus and direction of the lesson was often determined by ideas originating with students. If students are members of a true learning community, and if divergence of thinking is valued, then the direction that a lesson takes cannot always be predicted in advance. Thus, planning and executing a lesson may include contingencies for building upon the unexpected. A lesson that met this criterion might not end up where it appeared to be heading at the beginning.

IV. CONTENT: Knowledge can be thought of as having two forms: knowledge of what is (Propositional Knowledge), and knowledge of how to (Procedural Knowledge). Both are types of content. The RTOP was designed to evaluate mathematics or science lessons in terms of both.

Propositional Knowledge: This section focuses on the level of significance and abstraction of the content, the teacher's understanding of it, and the connections made with other disciplines and with real life.

6) The lesson involved fundamental concepts of the subject. The emphasis on "fundamental" concepts indicates that there were some significant scientific or mathematical ideas at the heart of the lesson. For example, a lesson on the multiplication algorithm can be anchored in the distributive property. A lesson on energy could focus on the distinction between heat and temperature.

7) The lesson promoted strongly coherent conceptual understanding. The word "coherent" is used to emphasize the strong inter-relatedness of mathematical and/or scientific thinking. Concepts do not stand on their own two feet. They are increasingly more meaningful as they become integrally related to and constitutive of other concepts.

8) The teacher had a solid grasp of the subject matter content inherent in the lesson. This indicates that a teacher could sense the potential significance of ideas as they occurred in the lesson, even when articulated vaguely by students. A solid grasp would be indicated by an eagerness to pursue student's thoughts even if seemingly unrelated at the moment. The grade level at which the lesson was directed should be taken into consideration when evaluating this item.

9) Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so. Conceptual understanding can be facilitated when relationships or patterns are represented in abstract or symbolic ways. Not moving toward abstraction can leave students overwhelmed with trees when a forest might help them locate themselves.

10) Connections with other content disciplines and/or real world phenomena were explored and valued. Connecting mathematical and scientific content across the disciplines and with real world applications tends to generalize it and make it more coherent. A physics lesson on electricity might connect with the role of electricity in biological systems, or with the wiring systems of a house. A mathematics lesson on proportionality might connect with the nature of light and refer to the relationship between the height of an object and the length of its shadow.

Procedural Knowledge This section focuses on the kinds of processes that students are asked to use to manipulate information, arrive at conclusions, and evaluate knowledge claims. It most closely resembles what is often referred to as mathematical thinking or scientific reasoning.

11) Students used a variety of means (models, drawings, graphs, symbols, concrete materials, manipulatives, etc.) to represent phenomena. Multiple forms of representation allow students to use a variety of mental processes to articulate their ideas, analyze information and to critique their ideas. A “variety” implies that at least two different means were used. Variety also occurs within a given means. For example, several different kinds of graphs could be used, not just one kind.

12) Students made predictions, estimations and/or hypotheses and devised means for testing them. This item does not distinguish among predictions, hypotheses and estimations. All three terms are used so that the RTOP can be descriptive of both mathematical thinking and scientific reasoning. Another word that might be used in this context is “conjectures.” The idea is that students explicitly state what they think is going to happen before collecting data.

13) Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures. This item implies that students were not only actively doing

things, but that they were also actively thinking about how what they were doing could clarify the next steps in their investigation.

14) Students were reflective about their learning. Active reflection is a meta-cognitive activity that facilitates learning. It is sometimes referred to as “thinking about thinking.” Teachers can facilitate reflection by providing time and suggesting strategies for students to evaluate their thoughts throughout a lesson. A review conducted by the teacher may not be reflective if it does not induce students to re-examine or re-assess their thinking.

15) Intellectual rigor, constructive criticism, and the challenging of ideas were valued. At the heart of mathematical and scientific endeavors is rigorous debate. In a lesson, this would be achieved by allowing a variety of ideas to be presented but insisting that challenge and negotiation also occur. Achieving intellectual rigor by following a narrow, often prescribed path of reasoning, to the exclusion of alternatives, would result in a low score on this item. Accepting a variety of proposals without accompanying evidence and argument would also result in a low score.

V. CLASSROOM CULTURE: This section addresses a separate aspect of a lesson and completing these items should be done independently of any judgments on preceding sections. Specifically, the design of the lesson or the quality of the content should not influence ratings in this section. Classroom culture has been conceptualized in the RTOP as consisting of: (1) Communicative Interactions, and (2) Student/Teacher Relationships. These are not mutually exclusive categories because all communicative interactions presuppose some kind of relationship among communicants.

Communicative Interactions: Communicative interactions in a classroom are an important window into the culture of that classroom. Lessons where teachers characteristically speak and students listen are not reformed. It is important that students be heard, and often, and that they communicate with one another, as well as with the teacher. The nature of the communication captures the dynamics of knowledge construction in that community. Recall that communication and community have the same root.

16) Students were involved in the communication of their ideas to others using a variety of means and media. The intent of this item is to reflect the communicative richness of a lesson that encouraged students to contribute to the discourse and to do so in more than a single mode (making presentations, brainstorming, critiquing, listening, making videos, group work, etc.). Notice the difference between this item and item 11. Item 11 refers to representations. This item refers to active communication.

17) The teacher's questions triggered divergent modes of thinking. This item suggests that teacher questions should help to open up conceptual space rather than confining it within predetermined boundaries. In its simplest form, teacher questioning triggers divergent modes of thinking by framing problems for which there may be more than one correct answer or framing phenomena that can have more than one valid interpretation.

18) There was a high proportion of student talk and a significant amount of it occurred between and among students. A lesson where a teacher does most of the talking is not reformed. This item reflects the need to increase both the amount of student talk and of talk among students. A "high proportion" means that at any point in time it was as likely that a student would be talking as that the teacher would be. A "significant amount" suggests that critical portions of the lesson were developed through discourse among students.

19) Student questions and comments often determined the focus and direction of classroom discourse. This item implies not only that the flow of the lesson was often influenced

or shaped by student contributions, but that once a direction was in place, students were crucial in sustaining and enhancing the momentum.

20) There was a climate of respect for what others had to say. Respecting what others have to say is more than listening politely. Respect also indicates that what others had to say was actually heard and carefully considered. A reformed lesson would encourage and allow every member of the community to present their ideas and express their opinions without fear of censure or ridicule.

21) Student/Teacher Relationships 21) Active participation of students was encouraged and valued. This implies more than just a classroom full of active students. It also connotes their having a voice in how that activity is to occur. Simply following directions in an active manner does not meet the intent of this item. Active participation implies agenda-setting as well as "minds-on" and "hands-on."

22) Students were encouraged to generate conjectures, alternative solution strategies, and/or different ways of interpreting evidence. Reformed teaching shifts the balance of responsibility for mathematical of scientific thought from the teacher to the students. A reformed teacher actively encourages this transition. For example, in a mathematics lesson, the teacher might encourage students to find more than one way to solve a problem. This encouragement would be highly rated if the whole lesson was devoted to discussing and critiquing these alternate solution strategies.

23) In general, the teacher was patient with students. Patience is not the same thing as tolerating unexpected or unwanted student behavior. Rather there is an anticipation that, when given a chance to play itself out, unanticipated behavior can lead to rich learning opportunities. A long "wait time" is a necessary but not sufficient condition for rating highly on this item.

24) The teacher acted as a resource person, working to support and enhance student investigations. A reformed teacher is not there to tell students what to do and how to do it. Much of the initiative is to come from students, and because students have different ideas, the teacher's support is carefully crafted to the idiosyncrasies of student thinking. The metaphor, "guide on the side" is in accord with this item.

25) The metaphor "teacher as listener" was very characteristic of this classroom. This metaphor describes a teacher who is often found helping students use what they know to construct further understanding. The teacher may indeed talk a lot, but such talk is carefully crafted around understandings reached by actively listening to what students are saying. "Teacher as listener" would be fully in place if "student as listener" was reciprocally engendered.

VI. SUMMARY: The RTOP provides an operational definition of what is meant by "reformed teaching." The items arise from a rich research-based literature that describes inquiry-oriented standards-based teaching practices in mathematics and science. However, this training guide does not cite research evidence. Rather it describes each item in a more metaphoric way. Our experience has been that these items have richly intuitive meaning to mathematics and science educators.

Further information about the underlying conceptual and theoretical basis of the RTOP, as well as reliability and validity data and norms by grade-level and context, can be found in the Reformed Teaching Observation Protocol MANUAL (Sawada & Piburn, 2000).

Appendix D: 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 = 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	SA A UN D SD

teaching science.

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 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

Riggs, I., & Knochs, L. (1990). Towards the development of an elementary teacher’s science teaching efficacy belief instrument. Science Education, 74, 625-6

Appendix E: Teacher Interview Questions

1. Describe your typical instructional unit?

   Probe for: scaffolding, instructional strategies, attitudes towards student learning, description of instructional resources, alignment with 5E model, etc.

2. Describe a typical laboratory experience.

   Probe for: inquiry approach vs. “cookbook” approach, student centered learning, peer dialog, connecting data to a larger concept, elements of the 5E model, etc.

3. What are some of your thoughts on the value of laboratory experiences for your students?

   Probe for: teacher efficacy and beliefs about inquiry learning and the 5E model.

4. What are some of your concerns about teaching the 2015 ACOS for science?

   Probe for: teacher efficacy regarding a conceptual approach to learning science.

5. Which professional development experiences stand out as particularly influential in your current classroom practices?

   Probe for: elements of professional development that the teacher uses in his/her classroom, professional development instructional strategies that influenced the teachers' practice, professional development organization, etc.

6. What experiences within your professional learning have influenced your beliefs and practices as a teacher? (classroom experience and/or outside learning)

Probe for: experiences that have shaped their knowledge about; teaching skills, ways to assess student knowledge and how students learn science.

Appendix F: Observations Themes

Group	Observation Variable	Evidence of Observation				
Group One		MH1	MT1	MH2	BP1	MP1
	Teacher acts as facilitator	X	X	X	X	X
	Teacher asks probing questions	X	X	X	X	X
	Teacher facilitates whole class reflection	X	X	X	X	X
	Teacher lectures between three and five minutes	X		X	X	X
	Students generate questions	X	X	X		X
	Students drive class discussions	X	X	X		X
	Students work effectively in groups with little teacher assistance	X	X	X	X	X
	Students are actively engaged in exploring phenomena (i.e. use of models, hands-on, discussion)	X	X	X	X	X
	Students freely ask questions in an informal manner	X	X	X	X	X
Group Two		BSV1	BCC2	BP2	AH2	MT2
	Teacher acts as facilitator			X	X	
	Teacher asks probing questions	X	X	X	X	X
	Teacher facilitates whole class reflection	X	X		X	
	Teacher lectures between three and five minutes					
	Students generate questions	X				

	Students drive class discussions	X	X	X		X
	Students work effectively in groups with little teacher assistance	X	X	X	X	X
	Students are actively engaged in exploring phenomena (i.e. use of models, hands-on, discussion)	X	X	X	X	X
	Students freely ask questions in an informal manner	X	X	X	X	X
Group Three		MH3	BCC1	BF1	BOG1	AH1
	Teacher acts as facilitator					
	Teacher asks probing questions			X	X	X
	Teacher facilitates whole class reflection	X	X		X	
	Teacher lectures between three and five minutes					
	Students generate questions			X		
	Students drive class discussions					
	Students work effectively in groups with little teacher assistance					
	Students are actively engaged in exploring phenomena (i.e. use of models, hands-on, discussion)			X	X	
	Students freely ask questions in an informal			X		

Appendix G: Interview Themes

Evidence of Reform Teaching

Group 1

Participant	Reference
BP1	1) I have really strived to, especially in the last 4 years to remove myself and to make sure that the class is as student led as possible and that I'm truly the facilitator. So I'm coming in to give you directions and guidance but I'm never coming in to give you the answer. It's been a struggle but that's my approach. 2) You take concepts that are pretty abstract and put the material in front of them that they can analyze. You can talk about photosynthesis all day, you can talk about cellular respiration all day but to put that in front of them where they can analyze it is a totally different thing.
MH1	1) It's a process (learning). It's almost like re-learning, you see it one way and then you learn something else so then you have to re-evaluate what you've already learned. 2) We just try and start with a foundation and build on it. 3) I think there is a time and place for everything, there are a few students that need to hear the information, so I do a little lecture but it's only like 5 or 10 minutes here and there.
MP1	1) It (lab activities) makes kids plan, and it also makes them think. When things don't work, you always have to figure something out. 2) The engineering, you know it's different ways for them to learn. 3) I like class discussion because I can tell a lot from a class discussion. But through class discussion I can tell,….do I need to stay on this another day. Your trying to meet your kids where they are.
MT1	1) I think learning is the teacher facilitating content, activities and the students actively taking a part in the learning process. 2) I like to have activities that allow them to explore without me giving them answers like ADI or investigations, critical thinking type activities where it doesn't require me talking, in the case of lecture I still try to make it where they can engage and participate and feel comfortable.

	3) A lot of times if I say things in a crazy way, they can talk to their partner and say, "this is how I understand it". Even building models if they ask each other questions and things like that

Group 2

Participant	Reference
BCC2	1) That's where I start, and then I look at what kind of things do they need before they get there. Then I hopefully can find a lab or some hands on thing that can get them there and that's where I start. 2) I've switched to flipped classroom, so I rarely lecture so like when I do it's like 10minutes maybe. 3) we're in the lab all the time but they just learn about how to design an experiment and how to take your results and make a conclusion from that and link it into the evidence. Its basically like how to be a scientist. And it's real world stuff, not just about science but if your arguing with someone about anything, you've got to have evidence to back it up, you can't just make no sense whatsoever and be rude.
BSV1	1) I'm wondering if students have a better understanding of the tangible stuff that they see around them. For example, certain aspects of climate change, they know about that. So if we start with that, then work backwards to micro and they see as you get into the micro how that connects. 2) I like them to think about something we've done previously or link it to something you know I try to follow the 5 E model, the engage that gets their attention and I really like inquiry, if I could teach everything through inquiry I would.

Group 3

Participant	Reference
AH2	1) I believe that if the teacher makes learning three dimensional, they present the material to all different types of learning. Make sure that it's visual, that they can get up out of their seats, that the teacher increases the chances of learning at some kind of level that there is going to be some be some kind of improvement. Even if it's not a 50% improvement it's like a 5% improvement will take place.

	2) If you can connect it with something in their memory, then they can access it real quick. It makes more sense. Scaffolding provides that frame of reference for the students. 3) Talk about it. A lot of students interact with it by allowing them to come up with questions about the concept. Elaborate and build something based on that concept. I skit or a play or a poem, one of things that I like is integrated art the science class because it's proven that students who struggle the most get the most gains when you incorporate that art activity. The brain, when you integrated that thing they get out of their seats they're excited about it. It gives them the opportunity to show off their skills and you are more than 100% guaranteed that you will touch on every student learning ability.
BF1	1) The biggest resource I use is POGILS I uh always use pogils those are good cause you can always use them as a whole class setting, a group setting or individuals. They are typically designed to be a group, it's easy to display them on a projector.
BOG1	1) Well they're looking at three different things, temp. pH, and substrate concentration. And so I think it gives them the data, because we combine data for the entire class. They have to look at the data and try to figure out why is the data the way it is, why do they get more bubbles here and fewer bubbles here,
MH3	1) They get the real-world connection when they experiment and they get so excited about it. I think it really helps their understanding about science.

Evidence of Traditional Practice

Group 3

Participant	Reference
AH1	1) (Learning) It's a combination of experiences and a told set of things, that plus the effort of trying to learn something. You can learn with someone who knows everything but until you actually put forth your part, you're not going to learn it.
BCC1	1) I talk about cells, I talk about levels of organizations, how it goes from subatomic particles and works its way up through the biosphere, or to find out, just an informal test about where students are, what do they know about cells, I would also pull in bacteria and talk a little more about viruses.

	2) I go over all the equipment for laboratory for a couple of days, they have a quiz on it, 3) I have them use the terms that we learned in class 4) sometimes we form a hypothesis in the classroom and then we, sometimes we just look and see what we can get. So like in the classroom we've gone over the steps of mitosis and they've seen the cells so we go to the lab and, you know I don't think they always relate what's in the classroom with what they see out there. So we have to come back and basically break down the lab and say that this is what they saw and this is what that meant. I had to do this a couple of times this semester, deconstruct it. 5) 16 standards, so that is less than two weeks per standard, and then you have sub standards under that so I think that standard 13 has A,B and C. and I think 11 has A,B and C, so already you're at 6 weeks over, cause you can't spend a whole lot of time doing lecture notes, 6) I don't know that giving them all inquiry based is good, I think that they need to have a balance, so that they can deconstruct you know maybe start them off just to see how they do but then you have students who have had very limited lab skills or laboratory opportunities so that is a hindrance. 7) "not every caterpillar becomes a butterfly" some will have an A, a B, a C and there will be some F's. The habit of education is always keeping them entertained, a part of educations is taking notes and a part of education is learning those notes. 8) I can't give them everything. I think if we just went back to the old way of teaching, you know if you got it, you passed the test and did the work then rigor, if you were allowed to fail a student, you know just let them fail that's enough incentive for you to do something, to stay in class, I can only do so much, I can engage you but I can't motivate you. That has to come from within.
BF1	1) I do use text quite a bit, I'll have them read the section so the actual text books that we have, I try to use some internet resources 2) The only labs that I do are something like a quick intro lab that's like a demonstration

	3) To be honest rote has been the best job with these guys, I know that that is exactly the opposite of what everyone is saying and wants to hear but it really helps.
BOG1	1) We would start with cell theory, do some microscope work, looking at specific slides, we may or may not incorporate a lab,

Evidence of Discomfort Teaching 3D Standards

Group 1

Participant	Reference
MP1	1) I don't know that there is a ton of difference between explore and elaboration

Group 2

Participant	Reference
BP2	1) They (3D Standards of 2015 ACOS) are deep the take a ton of planning and a lot of resources. 2) A lot of the developing models, it's trying to find the balance of working three days trying to develop the models while working of covering the concepts and covering the standards also. It's hard to do all of it.

Group 3

Participant	Reference
AH2	1) I just don't feel like I have the time and I struggle with how deep I'm supposed to go. I think the best ones to cut out are the ones that have been taught in life science in the 7th grade. There is some heavy stuff, we need to augment that or spread it out.
BCC1	1) They're not ready for it. The students are not prepared for it. (Teaching 2015 ACOS - 3D Standards) 2) They are not prepared for the rigor that it requires, um, I just don't have enough time to spend, the level of detail that the new standards require there is not enough time worked into the school, we have to do it all in one semester.

	3) I think we really should have kept the standards that we had and then used what we have now for maybe pre-AP or Honors because it requires more detail and it requires more abstract thinking, 4) But I think it's a mistake to think that all students are ready for that type of rigor, and to think that all of them want to go into biology because a lot of them don't.
BF1	1) In a way, the big challenge with the inquiry method with the 9th graders that I've had this year and the past couple of years is that they really have a difficult time making that jump from the basis of the apply what it is, basically the raw information and actually putting it into action, they struggle with that immensely, 2) while you are trying to talk about something and the person that is being disruptive is talking, yelling, throwing pencils and getting up and moving around the class kids cannot focus. There have been countless times that students have asked me if they can go to a different classroom or go to a library and get their work done because they cannot concentrate in this classroom.
BOG1	1) I think that the fact that they either all of them or most of them (standards) say create or use a model. Sometimes it's hard to plan when you're planning a lesson, even though models can be simple, they can be drawings and other things, that for me, I think I'm intimidated, OK, I have to think about how my kids can model this for me. That stumps me on my planning sometimes. 2) I know that modeling is what they need, I just get stuck on how they can do that. 3) there are so many standards and so little time. 4) I think my dream is to base every single lesson on a lab experience and almost teach everything as a CER and, but I can't, I don't have the resources or the time it takes to set up what I need and let them spend the time figuring things out. 5) and I feel terrible, at the end of every semester, I feel terrible because I either didn't get through the standards or get the depth that they needed or both
MH3	1) The standards are really advanced.

Evidence of Discordant Classroom Culture

Group 2

Participant	Reference
BP2	1) The difference in teaching levels is very, very large and so I feel like I could be doing a lot more if I had a class where I didn't feel like I was baby-sitting or crowd control. I like my second block, they're good.

Group 3

Participant	Reference
BCC1	1) They're not used to the rigor of the questions, they're not used to interpreting data, so that the details that you're looking for 2) I would like to have them come to class prepared, because they are not prepared. Even for final exams they are not prepared and I'm like did you take exams in 8th grade? 3) Often when I'm asked what do you do to motivate students, I have to ask what are they doing to motivate themselves.
BF1	1) they are still 9th graders and their maturity level is a little low and that leads to disruptive behavior in labs and distractions and horseplay to some extent and at that point it becomes disruptive and not very fruitful, so management at that point and dealing with the distractions so that the kids are actually focused can actually get the stuff done. 2) I don't know if it's their ability or um the lack of previous experience with that because no one has ever asked them to go the next step and I think that is what is 70% of the problem and then reading is about 30% of the problem and then the last 10 is want 3) Just the typical things, I saw it in this district and (system name) just um discipline is a huge issue and basically consequences for the disrupting students, the students, no matter how you try to approach it, parent phone calls, assignments, changing seats, write ups, um what have you. That behavior typically didn't change and there didn't seem to be any consequences for their actions.

BOG1	1) I've told you before that I really like this lab but I don't trust my children to do it, and part of it is just lack of experience. 2) sometimes you have a class that just is not going to cooperate, and you can't, they're not going to think, their not going to, and a barrier is that they're not coming in ready to think things through. They want to memorize if they study at all, and so to give them a question, it's like pulling teeth. 3) So sometimes I think you just have to put up with the mess to do what's best for your kids at the end and it's hard, they're just not cooperating. They don't understand that they'll be better off if they figure it out. Instead of just stand up and tell them stuff. They can't apply it and they can't transfer it.
MH3	1) the dragon genetics lab took 4 days and it shouldn't take that long if they knew something about genetics before they came in. 2) The kids this year are just more difficult. This is the first year I've had a class like this. I shouldn't say it but I'm thinking about nursing school.

Evidence of Positive Classroom Culture

Group 1

Participant	Reference
BP1	1) It's hard some days, this class did great with their CER but some classes, they don't even try. It makes it hard to see those end results. I have to tell myself everyday "it's worth it, it matters, the outcome is worth it".
MH1	1) I just came from a small town where everyone knows everyone and I think that influenced me. The teachers that were the best teachers were the ones who reached out to everybody.
MP1	1) I think the first thing is to understand how to work with your students. It has to be give and take. If it's all teacher lecture or all student, I don't think that's the optimum classroom, I think that you need to have both, sometimes it's more teacher, sometimes it's more student. There is a lot of cross chatter because they bring up things to each other. I think curiosity is a huge factor in this. 2) That idea that you don't have to be perfect but you need to give me your best. We got to get kids to think about potential, you know maxing your potential. I think this is something that I was taught.

	3) you have to be able to control a classroom, you have to have a rapport with the kids.
MT1	1) If the teacher is presenting, it goes hand in hand with the student and we kind of just work together, like a partnership. 2) I like discussions, I don't necessarily like a quiet classroom. I want them to feel comfortable. I want them to be able to ask questions, so a lot of times, even if it's a lecture I will pose different questions to them to keep them engaged. 3) I like them to feel like they can ask questions even if it's a silly questions or even if I feel it's a crazy question, I don't try to embarrass them. I don't ever want them to feel like they can't participate during class time so … 4) you need to build a relationship with them so that they can feel comfortable with you even if they don't feel comfortable in school. They need to feel like they are supported. It's a personal relationship, I personal connection that's important. Your relationship with those kids is what makes them want to work.

Group 2

Participant	Reference
BSV1	1) I'm older so I think that I interact with the kids a lot differently than some other teachers I'm definitely more open with them and more direct. 2) am fairly reflective and I want to improve what I'm doing.

Group 3

Participant	Reference
AH2	1) Throughout a typical day students spend more time at home than they do in the classroom and there are some variables that the teachers don't know that have a huge impact on the students' ability to learn and that the teacher has no awareness of. 2) if the teacher creates an environment of safety and welcomes and love of acceptance, applicability, and what I mean by that is to try and help the student understand how they can apply that to their life. Being citizens here on this planet. To me that's not too much, we can make some type of improvement in that students' life.

Evidence of Proficiency Teaching 3D Standards

Group 1

Participant	Reference
BP1	1) We were kind of uncomfortable with it (2015 ACOS) at first but pretty much it just took a restructuring of what we were already doing….like with the alkaptonuria lab it took just removing the inheritance pattern from the beginning changed the lab to make it more inquiry based. They enjoy it.
MH1	1) you have to let go of the old. It's just as simple as that. You can't, just because you love something doesn't mean that you can't try to move on.
MT1	1) I gave them the activity today to build a model but I didn't tell them a lot about it 2) It takes me having to do an activity to get to the end result of what we're learning. It provides that for them. I don't see not having labs incorporated somewhere in the lesson. In my opinion you cannot teach biology without labs. 3) I don't have a lot of concerns about teaching that (2015 ACOS)

Institutional Barriers

Group 1

Participants	Reference
MH1	1) Being able to have longer class periods, I just can't do everything I want to do in these short class periods.

Group 2

Participants	Reference
BCC2	1) All of the standardized testing takes up a lot of time. 2) There is just a lot of pushback from parents. 3) The past two years, from my experience, it's getting worse of putting limitations on teachers. You spend a lot of time doing things that aren't related to teaching science.

BP2	1) We have large class sizes, especially the biology.

Group 3

Participants	Reference
BF1	1) we don't have computers for everybody, 2) Well, just now I got a projector. I finally got a projector, I functioning projector, less than a month ago,
BOG1	1) Prep time being taken on a regular basis, schedules being changed that shortens classes, standardized testing which takes kids out of class, for multiple days in a row, I guess, time is one, resources, 2) I've been told to drop lessons before (evolution) 3) Parents are complaining, evolution. 4) I have outside pressures, and then there is always, you know they put 36 kids in my class and you know I can't feel safe enough trying to run a lab. 5) I haven't, the administration has been very supportive of me, I haven't gotten that from parents, I have gotten that from students
MH3	1) It's just that I have 172 students and we only have less than an hour for each class. It's really hard to do some of the activities that I'd like to do.

Institutional Support

Group 1

Participant	Reference
BP1	1) I have a really supportive administration. If I needed something I know they could make it happen also I have a lot of people who are supportive of me. So I know if there was something major, I can't think of anything that they would not provide.
MH1	1) We're lucky, we raised money, these are chrome books that we bought for the department. They want us to do field trips but I feel like we pulled in so many different directions that we can't but the faculty supports it.

MT1	1) I feel like the administration here is very supportive, anything that we can expose them to

Group 2

Participant	Reference
BCC2	1) In my case it's yes. Mine is OK (administrative support

Group 3

Participant	Reference
AH1	1) As long as it's within reason and appropriate (school support).
AH2	1) Our school provides all the tools.
BCC1	1) I think the environment I'm in is very receptive. The parents in this area are more supportive and if they want their kids to do right if they didn't do correctly then they know that.
MH3	1) Our administration is very supportive about letting us try whatever we want.

Misconception of Inquiry Learning

Group 3

Participant	Reference
AH1	1) I make sure that I do different things every day. There are the days that I do hands on activities, I don't necessarily have a time that I do certain things. I just try to keep every day a little different. With a different learning type, it might be hearing me one day and hands on.
MH3	1) I try to reach all the kids by doing some type of activity every day. The all have different learning styles and I try to meet them.

Appendix H: About Alabama Science in Motion

ABOUT ALABAMA SCIENCE IN MOTION (ASIM)

Alabama Science in Motion (ASIM) is the High School Component of The Alabama Math, Science, and Technology Initiative, commonly referred to as AMSTI, is the Alabama Department of Education's initiative to improve STEM teaching statewide, including improvements in the individual, as well as the integrated, STEM subjects. Its mission is to support Alabama educators and students in learning STEM through doing STEM.

AMSTI beliefs include:

- Equity – ensuring learning opportunities for all
- Expertise – delivering content and pedagogical knowledge and resources informed by evidence of effective practice
- Efficacy – maintaining high expectations for staff and stakeholders
- Empowerment - building sustainability and connecting STEM providers in Alabama communities
- Engagement – learning by doing for staff and stakeholders

AMSTI's motto is: Learning by Doing

AMSTI has three basic services: professional learning, resources, and onsite support. Schools apply to become official AMSTI Schools and, when accepted, agree to send all of their math and science teachers, and administrators to foundational training for two consecutive years. Teachers who attend training receive the resources needed to implement the lessons in the classroom. Additionally, schools agree to follow-up support during the school year delivered through coaching and professional learning communities.

Over its history, AMSTI has received both national and international attention for its effectiveness at raising achievement scores and improving student interest in math and science. Fortune 500 CEOs selected AMSTI as one of 35 "programs that work" from across the nation. AMSTI's effectiveness and accomplishments have been highlighted by the National Governors Association, The Smithsonian-National Science Resource Center, the National Council of State Legislators, Education Week, Science Generation: A National Imperative at the American Museum of Natural History Summit and others.

Appendix I: IRB Approved Informed Consent

Consent to Participate in a Research Study
University of Alabama, Tuscaloosa, AL

Title of Study: Reform Teaching in Alabama Science Classrooms

Investigator: Jill Chambers, Curriculum and Instruction, Biology Specialist, Alabama Science in Motion (ASIM) (205) 405-1560 jechambers@crimson.ua.edu

Introduction

- You are being asked to be in a research study regarding the elements of reform education practiced in life science classrooms.
- You were selected as a possible participant because you have participated in Alabama Science in Motion (ASIM) professional development for the years of 2016, 2017 and 2018.
- We ask that you read this form and ask any questions that you may have before agreeing to be in the study.

Purpose of Study

- The purpose of the study is to examine barriers which limit teachers' ability to implement reform pedagogical strategies in life science classes.
- Ultimately, this research may be used to influence the structure of ASIM professional development at the State level.

Description of the Study Procedures

- If you agree to be in this study, you will be asked to do the following things: Participate in two consecutive days of classroom observation. The investigator will be the observer. Observations will be accompanied by the Reform Teaching Observation Protocol (RTOP) and an ASIM Fidelity checklist. Participants will be asked to complete the Science Teaching Efficacy Belief Instrument (STEBI-A) and participate in a 30-minute interview.

Risks/Discomforts of Being in this Study

- There are no reasonable foreseeable (or expected) risks. There may be unknown risks.

Benefits of Being in the Study

- There are no individual benefits associated with participation in this study.

Confidentiality

- This study is anonymous. We will not be collecting or retaining any information about your identity. All data will be coded. Electronic data will be stored at UA Box, a secure site which adheres to federal regulations for the secure storage of research data.

UNIVERSITY OF ALABAMA IRB
CONSENT FORM APPROVED: 6/19/18
EXPIRATION DATE: 6/18/2019

Payments

- You will receive the following payment/reimbursement: Twenty-dollar VISA gift card for personal use. Payment will be issued at the end of the interview session. Payment will be issued through the PI's personal funds.

Right to Refuse or Withdraw

- The decision to participate in this study is entirely up to you. You may refuse to take part in the study *at any time* without affecting your relationship with the investigator of this study or standing with ASIM. Your decision will not result in any loss or benefits to which you are otherwise entitled. You have the right not to answer any single question, as well as to withdraw completely from the interview at any point during the process; additionally, you have the right to request that the interviewer not use any of your interview material

Right to Ask Questions and Report Concerns

- You have the right to ask questions about this research study and to have those questions answered by me before, during or after the research. If you have any further questions about the study, at any time feel free to contact me, Jill Chambers at or by telephone at (205) 405-1560. If you like, a summary of the results of the study will be sent to you. If you have any other concerns about your rights as a research participant that have not been answered by the investigators, you may contact Carpantato Myles, Research Compliance Officer, at 205/348-8461.
- If you have any problems or concerns that occur as a result of your participation, you can **report them to the Carpantato Myles at the number above. Alternatively, concerns can be** reported by emailing the Office for Research Compliance http://ovpred.ua.edu/research-compliance/

Consent to Record Interview Yes ☐

No ☐

Consent

- Your signature below indicates that you have decided to volunteer as a research participant for this study, and that you have read and understood the information provided above. You will be given a signed and dated copy of this form to keep, along with any other printed materials deemed necessary by the study investigators.

Subject's Name (print):____________________ Date:__________

Subject's Name (signature):____________________ Date:__________

Investigator's Name:____________________ Date:__________

Appendix J: IRB Approval for Research

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

June 19, 2018

Jill Chambers
Dept. of Curriculum & Instruction
College of Education
Box 870232

Re: IRB#: 18-OR-221 "The Struggle of Teachers to Implement Reform Practice in Biology Classrooms"

Dear Ms. Chambers:

The University of Alabama Institutional Review Board has granted approval for your proposed research.

Your application has been given expedited approval according to 45 CFR part 46. Approval has been given under expedited review category 7 as outlined below:

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

Your application will expire on June 18, 2019. If your research will continue beyond this date, complete the relevant portions of the IRB Renewal Application. If you wish to modify the application, complete the Modification of an Approved Protocol Form. Changes in this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants. When the study closes, complete the appropriate portions of the IRB Request for Study Closure Form.

Please use reproductions of the IRB approved stamped consent form to provide to your participants.

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

Good luck with your research.

Sincerely,