ADVANCED PLACEMENT BIOLOGY PROFESSIONAL DEVELOPMENT: A MIXED METHODS APPROACH TO INFORM QUALITY IMPROVEMENT

A Dissertation

by

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ABSTRACT

Reformed teaching strategies in science promote deeper conceptual understandings of how the world works. National reforms in K-12 science teaching have been recommended for decades, but science teachers tend to "teach as they were taught," limiting the reach of reforms. Effective 2012-2013, the College Board revised the AP Biology® course, materials, and training to align with reforms emphasizing student-centered practices. As an AP Biology® workshop facilitator, I was interested in the factors affecting the actual classroom implementation phase of reform. I asked: Will a workshop focused on science reforms change teachers' beliefs and improve confidence? Do changes in teachers' beliefs lead to behaviors changes in their classroom teaching, and what impediments reduce transfer to the classroom?

After the course revision, I pursued the answers to these questions as I facilitated two four-day workshops for forty new AP Biology® teachers. Using a mixed methods research approach, I collected data from participants including a pre-institute needs assessment, pre- and post-workshop responses on two surveys measuring beliefs, daily workshop reflections, and follow-up school-year interviews. I compared the quantitative data from the two surveys using matched pairs *t*-tests and subjected qualitative data to directed coding to examine theoretical alignment. I identified problems with classroom transfer using an activity theory lens.

Pre-post comparisons of workshop participants' responses on quantitative surveys indicated statistically significant positive changes in (1) reform-beliefs associated with behavior changes, predicted by Ajzen's theory of planned behavior, and (2) self-efficacy, predicted by Bandura's theory of self-efficacy. Qualitative analysis indicated some participants' schools possessed a supportive community for reform-based teaching, making reformed behaviors likely. For other participants, use of the activity theory lens allowed identification of tensions threatening the transfer of reformed strategies to their classrooms. These results indicate a need for supportive attitudes of stakeholders in and outside the school community (e.g., teachers, students, parents, and administrators), to increase student-centered science teaching in schools lacking a reformed culture. My recommendation for changes to my professional development curriculum was to specifically address the tensions I identified. While an important source of changed beliefs, however, professional development is only the beginning in assimilating reform.

DEDICATION

I would like to dedicate this work to my incredible family. First and foremost, this is dedicated to my husband Charlie. Thank you Charlie for all the behind the scenes work of day-to-day life that kept us on an even keel. You are my rock. To my mother Doris, who believed in me every step of the way. To my children, Christina, Chelsea and John, you were the best cheerleaders I could have ever hoped for. To Katherine, Emilia, Alexander, and Jacob, always remember anything is possible. I thank you all for supporting the realization of my dream.

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I completed all work for the dissertation, under the advisement of Carol L. Stuessy of the Department of Teaching Learning and Culture.

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The contents of this dissertation are solely my responsibility as the author and do not necessarily represent the official views of Texas A & M University or the College of Education and Human Development.

NOMENCLATURE

AID	Accommodating Individual Differences (TEBS-Self Category)
APSI	Advanced Placement Summer Institute
AP® Biology	Advanced Placement Biology®
BARSTL	Beliefs About Reformed Science Teaching and Learning
CC	Communication/Clarification (TEBS-Self Category)
CHAT	Cultural Historical Activity Theory
CLE	Characteristics of Teachers and the Learning Environment (BARSTL Category)
CM	Classroom Management (TEBS-Self Category)
FCI	Force Concept Inventory
HOTS	Higher Order Thinking Skills (TEBS-Self Category)
HPL	How People Learn About Science (BARSTL Category)
LDI	Lesson Design and Implementation (BARSTL Category)
MC	Management/Climate (TEBS-Self Category)
MS	Motivation of Students (TEBS-Self Category)
NOS	The Nature of the Science Curriculum (BARSTL Category)
PCC	Maintaining Positive Classroom Climate
PCE	Positive Classroom Environment
Pre-AP	Commonly refers to a course before AP Biology®
SCLE	Student Centered Learning Environment

STEM	Science, Technology, Engineering, and Mathematics
STS	Science, Technology, and Society
TEBS-Self	Teachers' Efficacy Beliefs System-Self Form
TRA	Theory of Reasoned Action

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CHAPTER I

INTRODUCTION

My life history has given me an unusual perspective on my dissertation topic concerning reforms in science teaching and learning. This topic is not obscure history for me, but rather lived experience from 34 years of science teaching. I remember the small white paperback, *Science for All Americans* (American Association for the Advancement of Science, 1990), and the larger *National Science Education Standards* (National Research Council, 1996) arriving in the science office, yet I am struck by the lack of attention to them. The importance of these documents, the why and how of science reform, was overshadowed by the consuming task of teaching.

A 34-year career as a science educator resulted in my highly reformed beliefs and practices, but I cannot point to a single event that led me to these reforms. The reform documents did not arrive at the high school where I was teaching with a shout, but rather a whisper. Reforms slowly entered my science teaching through the channels that immediately touched my day-to-day work in the classroom. Technology and textbook changes accelerated the pace at which I found and used strategies and materials consistent with reform. The reforms in the College Board AP Biology® program (The College Board, 2013) cemented and validated my student-centered, constructivist approach to teaching and learning. When I began this dissertation, I would have told you my reformed beliefs and teaching style evolved through years of successful experiences with students. In hindsight, this is an oversimplification; I became a reformed teacher because the landscape around me changed, and I was receptive to these changes. This pace is unacceptable today. The need for scientific literacy for all citizens is much more critical today than when *Science for All Americans* (American Association for the Advancement of Science, 1990) was first published.

A great need for change exists. The reform documents are a vital and powerful roadmap for scientific literacy, but the changes in them must move into all classrooms now. The decades old arguments (American Association for the Advancement of Science, 1990), for developing a scientifically literate and scientifically wise society through science education, hauntingly foreshadowed the needs we are faced with today. These arguments in summary are: (a) science is needed to provide knowledge and solutions to global and local problems, (b) science fosters awareness of, and respect for, the fragile interconnections upon which we our lives depend, (c) scientific training prepares members of a society to weigh evidence and think critically, protecting them from hidden agendas, (d) science gives people the tools they need to evaluate technologies, for risk versus reward, to move beyond short-term self-interest, (e) science and technology advancements are needed to solve problems, even while recognizing some problems are a creation of technology itself, and (f) only through a scientifically literate society are we likely to protect and better the world (American Association for the Advancement of Science, 1990, p. xiv).

My research is important because society does not have time for today's science teachers to arrive at reformed ideas through the "landscape" mode as I did. Even teachers nationally recognized for excellence receive little information about reforms through national reports (Burton & Frazier, 2012). Reform based science teaching is urgently needed today, in all classrooms, for all students. The reforms must be transparently modeled and explicitly stated in professional development settings to reach practicing teachers. This study opens a window on the production of a state of reformed beliefs (which then leads to reformed practice) among today's teachers. The study helped me understand events within professional development that are associated with changes in beliefs about science reforms and increases in teachers' confidence in the classroom. Though this research is not generalizable, activity theory (Engeström, 2015) pulled me back to a vantage point where I could see the overall workings of a professional development event, and the activity systems it is intertwined with, such as teaching in the schools, to begin to understand how interactions between the systems affect the transfer of changes in beliefs to changes in classroom teaching behavior.

Theoretical and Conceptual Framework

Pragmatism is my philosophical foundation for this mixed methods study. Pragmatism allowed me to use a philosophical framework based on specific assumptions about ontology, epistemology, and axiology. In a pragmatic worldview, the ontological and axiological elements of this philosophy had a post-positivist approach during the collection of quantitative data, but allowed for multiple perspectives when the data involved was qualitative (Creswell & Plano Clark, 2011). I acknowledge the conflict between the quantitative, post-positivist view and the opposing qualitative philosophy by using a pragmatic philosophy, but I followed the lead of many who use mixed methods by choosing to intertwine the two. In the pragmatic epistemology, practicality rules, and the individual conducting the study uses whatever methods are best suited at various study stages (Creswell & Plano Clark, 2011).

Activity theory provided a wide lens that accommodated the quantitative and qualitative connection in a mixed methods approach. The goal of activity theory is to understand human activity (DeVane & Squire, 2012). It was a useful tool for the purpose of this study because it provided a framework for identifying the components of relevant activity systems, and served as an analytic tool that exposed contradictions and tensions within the professional development activity system, and other associated systems. The activity system framework may be found in Figure 1. Contradictions are not inherently

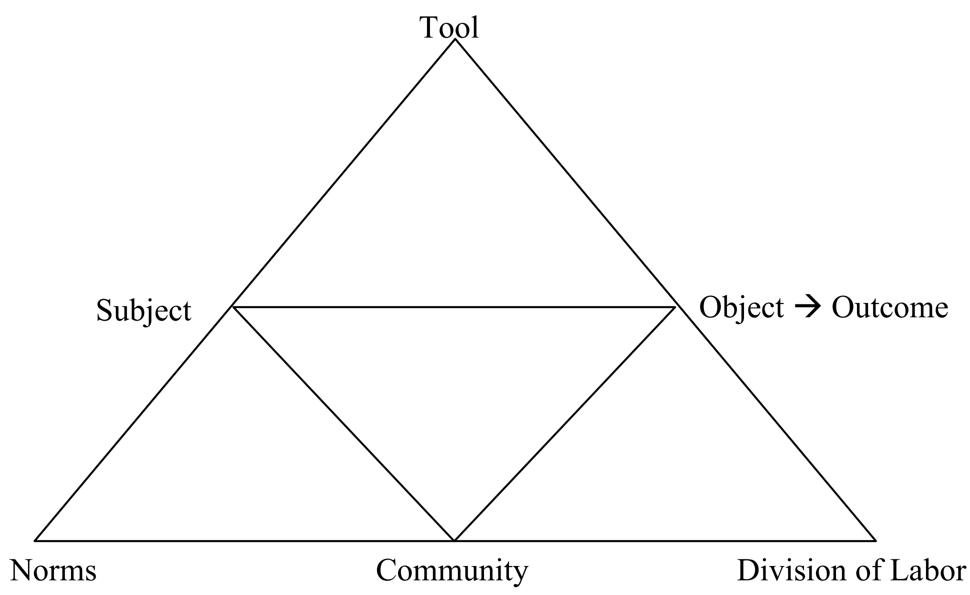

Figure 1. Activity theory framework. Adapted from "Structure of Human Activity," by Y. Engeström, 2015, *Learning by Expanding*, *Origins, applications, and challenges* (2nd ed.). New York, NY: Cambridge University**.** p. 63.

value laden; they are simply the exposure of cognitive dissonance between what workshop teachers currently believe and workshop experiences regarding reformed practice. A second type of contradiction is that between beliefs changes associated with the APSI and school-based realities that affect implementation of related behaviors in the classroom. As the identification of contradictions is such an important concept in the overall work, I have provided several examples in Table 1. All of the data sources in this study were used to identify the relationships between teachers' commonly held beliefs and workshop attendance. Identifying these relationships and examining contradictions helped me to understand how activities within a professional development workshop were associated with changes in teachers' beliefs, and how those changes were manifested in behavior changes that affect classroom instruction. Furthermore, using activity theory provided a glimpse into interactions in the school setting that hinder the transfer of belief change to behavior change. A detailed analysis of this sort will provide direction for improving and refining professional development experiences having direct correspondence to changes in teachers' beliefs.

I used several theoretical lenses in interpreting the results of the study. The first was Bandura's theory of self-efficacy. Bandura (1997) defines self-efficacy as "a belief in one's personal capabilities" (p. 4). This theorist notes several ways self-efficacy can be changed; of these, I found three to be particularly relevant. First, a person needs to experience success at difficult tasks; second, persons benefit from social modeling when they see someone like them succeed; and third, persons benefit from positive views of their actions shared with them by others. My workshop of reform-based practices was

Table 1

Illustrative Examples of Contradictions and Resolutions in an APSI Workshop and Related System

Contradictions		Resolutions
Subject (participant) believes a transmission model is the only way to cover AP Biology content.	Tools are used that provide content in a student-centered, active learning approach.	Subject (participant) sees transmission model is not the only way to approach this content. They then weigh the value of the approaches and may change their beliefs about this reform-based activity. Community support influences the normative beliefs about this reform. Evidence from an interview may show the new Tool was successfully used in the classroom. The contradiction is resolved by practice. (Professional Development→Belief change→Behavior change→Student success.)
Subject (participant) has difficulty directing student centered inquiry labs.	Reform-based Tools, include inquiry labs, but subject feels lack of Community support evidenced by lack of inquiry experiences for students in previous years.	Subject (participant) learned or refined strategies for teaching inquiry. The behavior change may be desired by the Subject (participant), but resisted by the student Community. A resolution controlled by the Subject involves dropping down to a more supported level of inquiry. This makes us aware of larger scale resolution-earlier inquiry experiences. (Professional Development→Belief change→Behavior change must be modified for student success.)

designed to change efficacy expectations by providing mastery experiences, modeling success, and encouraging participants.

I used the theory of planned behavior (Ajzen, 2005) to explain the connection between beliefs and behavior. Activities within the APSI were intended to change teacher beliefs in two areas, self-efficacy, and beliefs about science teaching reforms. It is not enough to change beliefs; there must be a connection between belief change and behavior change in order to make a difference in the classroom.

I used Desimone's (2009) *Core Conceptual Framework for Studying the Effects of Professional Development on Teachers and Students* as a conceptual organizing principle (see Figure 2). I was interested in how effective professional development, based on science education reforms, could transform teacher beliefs. The theory of planned behavior (Ajzen, 2005) provided a pathway connecting belief changes to behavior changes. Using this theory, teacher interview data was used to connect belief change to behavior change in the classroom. I thought teachers who became more confident in their science teaching ability, and who embraced a more reformed teaching philosophy, would exhibit behavior changes that lead to improved student success, the ultimate measure of a successful professional development experience.

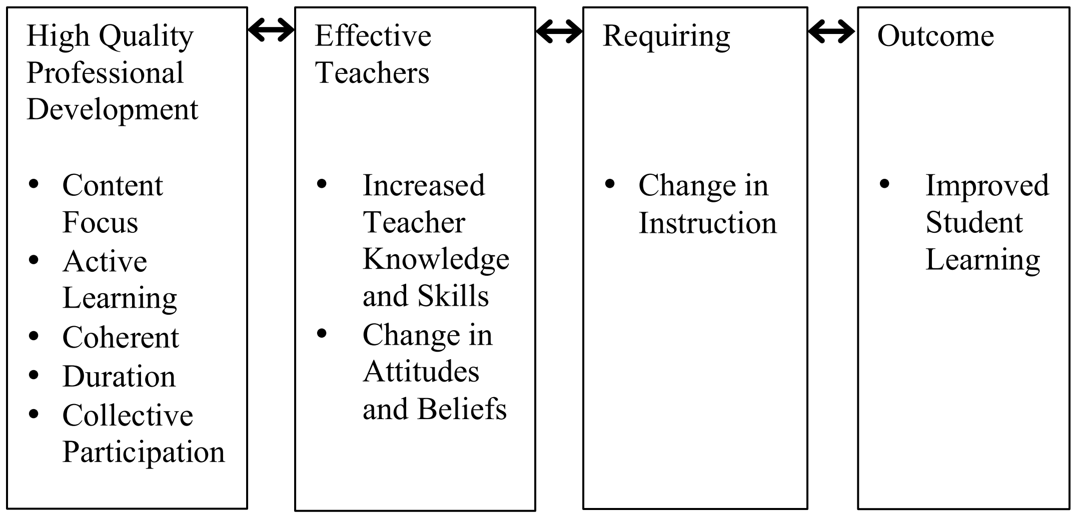

Figure 2. Conceptual framework connecting areas of interest for proposed study. Adapted and modified from "Improving impact studies of teachers' professional development: Toward better conceptualizations and measures," by L. Desimone, 2009, *Educational Researcher, 38*, p.185.

Problem Statement

Each school year, college-bound students look forward to their new schedule of Advanced Placement (AP) classes with excitement and anticipation. School administrators, parents, and students all share a vision of the perfect teacher for these classes. Teacher turnover is inevitable. However, in an ideal world, every newly assigned Advanced Placement Biology (AP Biology) teacher would walk into the classroom self-assured and with the knowledge and skill of a master teacher. Unfortunately, this is not the norm.

In reality, many newly assigned AP Biology teachers lack confidence in their ability to teach the course. They often lack knowledge of reforms in science teaching, and have few skills in organizing and managing complex, inquiry-based, quantitatively rich lessons required by recent College Board reforms. New AP Biology teachers participating in professional development have expressed concerns to me regarding their ability to change their teaching styles. Teachers often lack experience with active learning, both as teachers and as students. They know what inquiry learning is, but they lack success in classroom orchestration. Furthermore, the need to apply quantitative skills is new to them, even though the rigorous AP Biology content requires that teachers include development of quantitative skills in their instructional objectives for their students. In many cases, their lack of success is a legacy of their own biology education, which was delivered and learned in a predominantly transmissive mode, focused on the mastery of biological content and not on the use of quantitative skills.

Unless new AP Biology teachers are well trained in quantitative application and reform-based methods, AP Biology students will suffer. Unprepared teachers who lack the skill and confidence to deliver an effective course will teach the students. If the teachers do not leave an Advanced Placement Summer Institute (APSI) confident and prepared to teach in a reformed mode, the students will be taught in a "sage on the stage" method accompanied by cookbook laboratory experiences that will not prepare them for success on the AP Biology exam. The students in these courses are often very interested and motivated in science. If they have positive experiences they are likely to continue with science in college, but negative experiences will often mean one more leak from the pipeline as they end their science training. Teachers trained in active learning pedagogies who understand the reforms in science education are essential in the retention of this highly interested and motivated segment of students in science.

The revised AP Biology curriculum is based on reforms in science education. Without teacher training and practice, however, the goals of a reform-based course cannot be realized. As a provider of AP Biology professional development, I delivered a reform-based workshop that provided participants with student-centered active learning, inquiry, and math-science integrated experiences. In my role as the facilitator, I am free to personalize the workshop by choosing specific teaching methods and content within the program. In the workshops that were the context for this study, I enabled my AP Biology participants to experience inquiry, work with AP Statistics participants, and share in a model of overall active learning. I looked for evidence of successfully meeting the needs of my participants including higher self-efficacy, and more reformed beliefs about science teaching to answer my guiding question for my study:

> *Will a focus on student-centered activities consistent with science reforms change teacher beliefs about those reforms, and will it make teachers more confident about their ability in this area?*

The results of this study should influence many audiences. The most immediate audience, of course, is my dissertation committee, who must agree that this study is of value. Other individuals who will benefit practically from this work are AP Biology students who stand to earn more college credit, their parents who save money on tuition, the AP teachers themselves who will experience more success in their students' outcomes, and AP Biology Consultants who will be able to use the information to enhance their workshops. On the institutional level, high schools should also benefit as their reputations are boosted by better AP performance. The College Board will be interested in adjustments to training that leads to greater student success. APSI directors and researchers in science education may review results with an eye toward unmet challenges that prevent professional development successes from being fully realized at the school and classroom level. Finally, colleges and universities may use this research to consider the impact of students entering their programs that have been trained with a constructivist approach rich in higher order thinking and open inquiry investigations. They may question how to prepare students to be ready and eager to move further, deeper, and faster than those who have come before. As a society we are concerned with the flow of talent to science careers. Prepared AP Biology teachers and a successful AP Biology course is a step toward this success.

Purpose of the Study

The purpose of this mixed methods study was to understand the connections between a professional development event, and, beliefs and classroom behavior changes. An embedded research design was used in which the quantitative survey data about beliefs was embedded within a qualitative case study approach (Creswell & Plano Clark, 2011) using both a theoretical and activity theory lens . Pre-post quantitative data were collected to measure the effect of the APSI on two dependent variables. The dependent variables are the mean score differences on the BARSTL (Sampson, Enderle, & Groom, 2013) and the TEBS-Self (Dellinger, Bobbett, Olivier & Ellett, 2008). The BARSTL is a measure of reformed beliefs and the TEBS-Self is a measure of teacher self-efficacy. Participants were interviewed to discover how they experienced the APSI and how it affected their classroom behaviors. I used activity theory as the framework through which I sought to understand contradictions within an activity system *Teaching AP Biology*, defined here as the experience of using or attempting to use the student-centered, reform-based practices associated with the APSI professional development experience, and related activity systems. My goal was to understand the quantitative changes in beliefs through the qualitative data, examine evidence of behavior changes and related theoretical support, and illuminate contradictions with the potential to reduce the transfer of these beliefs and behavior changes.

Significance of the Study

The Current State

We need a scientifically literate population to deal with many issues we face today on planet Earth (American Association for the Advancement of Science, 1990). These include climate change, energy needs, and environmental decline, along with ethical issues surrounding what science *can do* versus what it *should do*. The average citizen has not shown or needed great scientific understanding in the past, but with the pressing need in our society for a population that can think critically and creatively about our problems, educators must be the best prepared in history. Young people today need the capacity to understand and appreciate scientific arguments in order to be prepared for the future, yet science literacy is not common to most Americans (American Association for the Advancement of Science, 1990, p. xv). The United States produces some of the best scientists in the world (American Association for the Advancement of Science, 1990), but the gulf has been widening between those who produce scientific work and the rest of the population. Growing distrust in science is a problem that must be changed within education.

A Nation at Risk (Gardner, 1983) declared educational mediocrity an enemy of our national prosperity. Many national reports find we need a full and fluid flow of talent in the pipeline to STEM (science, technology, engineering, and mathematics) careers to maintain our competitiveness as a nation, but many students have trouble staying in the pipeline. This is particularly true of under-represented groups such as females, minority students and those from low socio-economic backgrounds.

I believe the lack of understanding of complex scientific issues, and the trouble retaining talent in the pipeline toward STEM careers, are related. Both result from students being disillusioned with science. They often perceive science as a rigid set of "truths" to be learned devoid of human contemplation. They may be ill prepared, especially in mathematics. If the STEM career pipeline is full it means science education is healthy, and if it is healthy we will be preparing scientifically literate citizens.

Recent research has found that active learning pedagogies make a difference in STEM student success (Freeman et al., 2014). Active learning includes strategies such as inquiry, problem based learning, project based learning, and case based learning (Prince & Felder, 2006). Since we know active learning makes a difference, how do we enhance the use of these strategies in STEM classrooms including biology? Professional development is critical to preparing current teachers to adopt these reformed teaching ideas (Wood, 2009).

The road to effective science teaching pedagogies started with reforms in science education. The AP Biology Curriculum Framework (The College Board, 2015) shares elements with *Next Generation Science Standards* (National Associations of School Boards of Education, 2014), which are built from a *Framework for K-12 Science Education* (National Research Council, 2012). These standards are based on a student-centered, active learning approach.

Justification of Significance

National call. A scientifically literate society has never been more important. We are facing unprecedented environmental change and we cannot squander talent. All Americans, including those belonging to under-represented groups, must have the opportunity to be taught science in ways that are shown to be effective to both develop their talent, and maintain their interest in science (American Association for the Advancement of Science, 2011).

Local call. The AP Biology curriculum has recently undergone a major reorganization that reflects the reforms in science teaching (The College Board, 2013). The new course was designed to be deep rather than wide, with an emphasis on process referred to as "science practices." Teachers come to training institutes holding beliefs about reform that are all along the beliefs continuum and possessing different degrees of self-efficacy regarding their ability to teach biology. An AP Biology workshop that changes beliefs is importance because these changes in reform beliefs and self-efficacy are tied to improvements in student performance and retention in science through changes in teacher behavior. To further improve professional development, it is important to know what aspects of the professional development experience made a difference to the participants. It is important that the philosophy of the AP Biology framework and the philosophy of the workshop align.

Individual call. Practitioners face enormous time pressures and often have trouble staying up to date with research findings that can have big impacts on their students. It is important to provide professional development that models these findings, including active learning and inquiry teaching. Lessons that model reform-based strategies increase teacher confidence and lead to more reform-based teaching behaviors in the classroom.

Desired outcomes of this study. My goals were: (1) to investigate whether APSIs in biology are associated with changes in teachers' reformed beliefs and confident in their ability to teach biology, (2) examine the alignment of these changes with predictive theory, and (3) examine issues with the transfer of reformed behaviors to the classroom. Teachers who are reform minded and have a high sense of self-efficacy are more effective teachers, increasing the number of students who stay in the STEM career pipeline and increasing the percentage of the population who are able to understand and evaluate complex problems in science. Understanding changes in teacher beliefs and behaviors associated with professional development steeped in reform, and recognizing and reducing problems with transfer of reformed behaviors from professional development to the classroom is critical to our future.

CHAPTER II

LITERATURE REVIEW

I lived through the science reforms. I was born a few months before the launch of Sputnik, which definitely influenced national concerns, as well as elementary school teachers, about developing scientists for the race to the moon. To tell the truth, I taught through these science reforms too. I would like to think I found my own way to an understanding of reformed beliefs and active learning during my 34 years as a science teacher, but I may be overreaching. When I step back and look at the landscape, I see a different reality. My reformed teaching practices were not built in a vacuum. I had mentors and talented colleagues who were encouraging, but the most significant influences in my teaching were from high quality professional development.

A single teacher can change his/her beliefs about reform by seeing reformed teaching modeled by a peer or instructional coach. He/she can also gain self-confidence by having successful attempts using a reformed practice that he/she has just observed, particularly if a mentor is handy to provide assistance and support. Current theories of human behavior explain the relationship between beliefs, behaviors, and eventual outcomes. In terms of teaching, the progression of events leading to improved student achievement begins with a change in teachers' beliefs and levels of self-efficacy, which then moves to a change in teachers' instructional behaviors, and eventually leads to increasing students' achievement. Modeling reformed practices and providing mastery experiences within a professional development workshop, however, has the potential to change beliefs and increase confidence for more than a single teacher. Professional development learning environments for teachers have the capacity to influence the beliefs and confidence of many teachers at the same time. Relying on reformed, socio-cognitive approaches, the professional development provider can create a community of learners in which other teachers, as well as the instructor, work together to make sense of unfamiliar reformed teaching practices, experience them in a non-threatening environment, and influence positive changes in the levels of self-efficacy and reformed beliefs teacher participants originally held before the workshop began.

I was encouraged by the recent redesigns in the College Board AP® Science programs, which were built on the foundation of national reforms. Biology was the first AP program redesigned. A new laboratory book (The College Board, 2012) replaced “cookbook labs” with much improved inquiry-based experiences. While the process also included a content overhaul, the most important change was a conceptual one to teach less content with more depth (The College Board, 2011). Professional development consultants endorsed by the College Board were retrained on the new student-centered, reform-based program. Many of these consultants train teachers in weeklong summer workshops collectively referred to as APSIs (Advanced Placement Summer Institutes). I am such a consultant, and I have provided APSI workshops in AP Biology for 13 years. For the past three summers, I have redesigned my APSI workshop to model reform-based teaching. With considerable reading and reflection, I have grown to believe that the key to implementing reformed-based practices in AP classrooms resides within the beliefs and self-efficacy of AP Biology teachers. With theoretical underpinnings guiding my quest for “the key,” I posed this overarching question:

> How effective is a redesigned Advanced Placement Summer Institute (APSI) in changing teachers’ beliefs about science education reform and increasing teachers’ self-efficacy regarding their abilities to teach the course?

This preliminary research, I believe, was an essential first step in supporting and scaling up a new professional development model that not only increases reformed beliefs but also changes teachers’ feeling of efficacy in being able to implement reform in their own classrooms. The findings of this initial study are not generalizable beyond the APSI workshops for which I am responsible. However, I believe that intense, personalized research at a small, localized scale using mixed methods was an important starting point. While I desired to document changes in teachers’ beliefs and self-efficacy, and I also wanted to hear from teachers about their perceptions of the effects of the APSI after they have implemented reformed practices in their classrooms.

In preparation for this work I have examined relevant literature in a number of areas, which I have clustered into six sections:

Section 1: Activity Theory as a Key to Understanding

Section 2: The Abbreviated History of Science Education Reform

Section 3: Professional Development and Science Reform

Section 4 Active Learning: A Core Professional Development Competency

Section 5: Beliefs and Behaviors

Section 6: Additional Research Needs and Next Steps

In Section 1, I examine activity theory as a theoretical/conceptual framework for analyzing professional development. In Section 2, I provide a short history of reform in science education in the United States, particularly in reference to how current reforms connect to the recent redesign of AP Biology. In Section 3, I connect reform to the professional development needs of science teachers, as reforms reach science teachers most often through teacher professional development. In Section 4, I discuss active learning, a major change in pedagogical practices that previous researchers have shown to be effective in improving student learning outcomes in science and mathematics. This student-centered approach is consistent with recommendations in national reform documents. In Section 5, I connect professional development to change in beliefs, both beliefs teachers hold about reforms and their beliefs about self-efficacy. In this section, I also include an overview of the instruments used to measure beliefs and outline the theories connecting beliefs with behavior. In Section 6, I conclude with future research needs and next steps.

Activity Theory as a Key to Understanding

Origins of Activity Theory

Human behavior is complex. Early behaviorists studied human action and thinking at the individual level (Jonassen, 2000). The “stimulus-response framework” used since the 1880s was then considered forward thinking due in part to its similarity to scientific methods of the time (Vygotsky, 1978, p. 59). Vygotsky (1978) noted humans were social beings with behavior more complex than this straightforward stimulus-response model implied, and therefore the stimulus-response model was inadequate for study of higher human psychological processes. He developed a new model based on a view of man and nature in which not only did nature change man, but man also changed nature particularly as he used tools. Vygotsky converted the linear stimulus-response model into a triangle by the addition of a point that represented a sign or Tool, and he emphasized the importance of the mediation or two-way nature of this connection. This new interactive social-cultural model provided a framework within which complex human behavior could be examined leading to the development of activity theory. Vygotsky's student, Leont'ev, expanded this model when he added more connections (DeVane & Squire, 2012). This new model referred to as activity theory or Cultural Historical Activity Theory (CHAT) reflected human interactions in a cultural and historic world. Commenting on the direct connection from Vygotsky to Leont'ev, Engeström wrote, "Activity theory, is the most important heir and extension of Vygotsky's legacy" (Engeström, 2015, p. xiv).

What is Cultural Historical Activity Theory?

Cultural Historical Activity Theory (CHAT) is not a research method. Rather, it is an analytic tool that allows analysis of interactions within a system (DeVane & Squire, 2012). Engeström generated the graphic associated with this expanded activity theory that illustrated a collective action (see Figure 3). Activity theory describes learning as a result of activity not something that precedes activity (Jonassen & Rohrer-Murphy, 1999). In this second-generation CHAT, a second layer of three triangles was added with nodes that represented social rules or Norms, Community, and Division of Labor.

Jonassen and Rohrer (1999) described the nodes and interactions of the top triangle in general terms and in specific terms of the design of a constructivist-learning environment. They identified the Subject as the person or people involved in driving the activity, the Object as the learning product desired from the activity, whether a concrete physical product or a mental product, and the Goal (also called an Outcome) as the expectation the designer has for the constructivist-learning environment activity. Objects are used to assess the learners' progress in achieving the expectation (i.e., the Goal) resulting from the activity. (For example, a poster outlining the results of an experiment could be an Object created by a group of students; the Goal, however, could be students' understanding of the scientific process.) Tools are anything used by the learners in the transformation of the Object. For a constructivist-learning environment, Tools could be models, methods, hands-on manipulatives, technology, curricula, or even language – whatever students use in creating the Object. The Community agrees to a set of Rules or Norms as it engages in the activity; these rules are related to the Division of Labor as the Community works toward the creation of the Object and the eventual achievement of the Goal of the activity. The designer must continuously analyze the activity, contextually and inclusively, to assess the facility of the various components of the activity system in supporting students' creation of Object and progress towards the Goal of the activity system. Multiple interactions are possible between Subjects, Tools and Community (including Division of Labor and Norms), their relationship to the Object, and their roles in achieving the eventual Goal (Outcome).

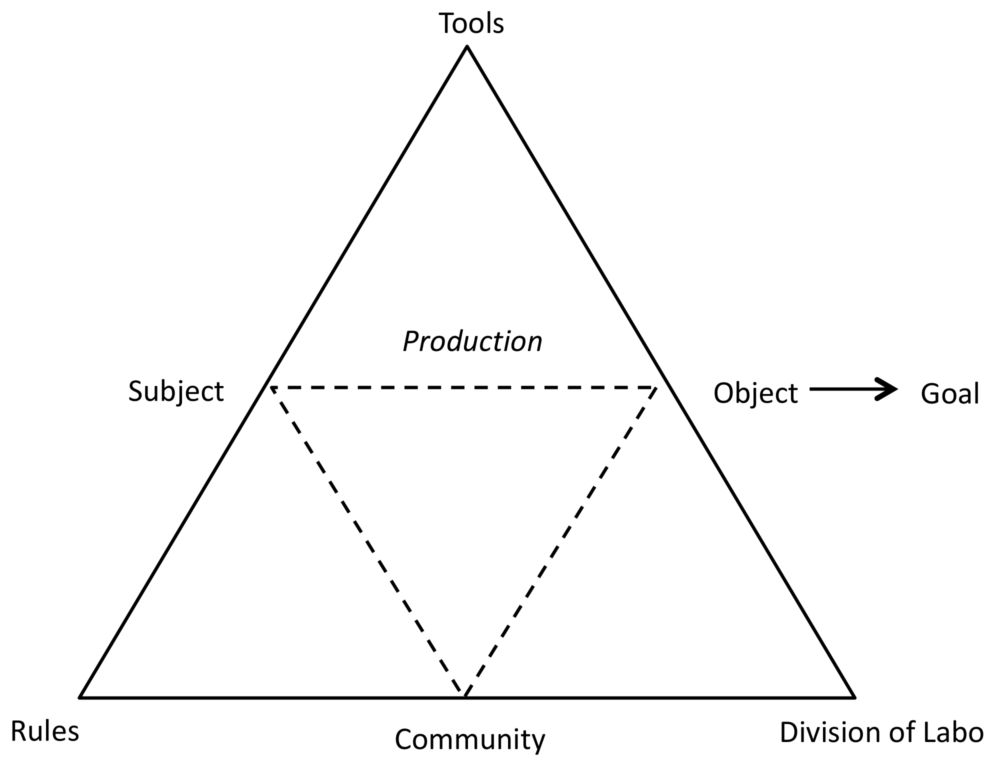

Figure 3. Engeström's model for an activity system (on the basis of Engeström, 1987). Adapted from "Activity theory as a framework for designing constructivist learning environments," by D.H. Jonassen and L. Rohrer-Murphy, 1999, *Educational Technology: Research and Development, 47*, p. 63.

Activity theory has been used to study a variety of systems including technology (Murphy & Rodriguez-Manzanares, 2014), formative assessment (Crossouard, 2009), and collaborative action research (Feldman & Weiss, 2010). Activity theory, specifically CHAT, has also been used as a tool to analyze professional development (Bourke, Mentis, & O'Neill, 2013; Herbert, Campbell, & Loong, 2016). Herbert et al. (2016) used the theory to analyze an on-line professional development program for rural science and mathematics teachers in Australia; these researchers used a multi-voiced perspective by considering both the facilitators and the participants as subjects. They placed the results of their thematic analysis of interview transcripts into an activity system and found the cost of professional development was a source of tension in the system. Bourke et al. (2013) examined a professional learning and development program designed to help teachers use narrative assessment with high needs students in New Zealand. They recognized tension in the system that was preventing their professional learning and development program from being successful. In both cases, CHAT helped uncover tensions that needed to be recognized in professional development.

Activity Theory in Education

Activity theory has a reputation as "unfriendly and foreign" due to its origins in Soviet and German philosophical and psychological traditions (Murphy & Rodriguez-Manzanares, 2014, p. 20). In spite of this perception, Murphy & Rodriguez-Manzanares (2014) found activity theory a valuable framework with which to study activities involving learning. Activity theory is a particularly suitable framework for the analysis and development of the interacting components involved in design of a constructivist-learning environment (Jonassen & Rohrer-Murphy, 1999). Jonassen and Rohrer-Murphy (1999) declared activity theory a "powerful framework" (p. 62) for the work associated with designing constructivist-learning environments. Jonassen (2000) found activity theory useful when designing student-centered learning environments (SCLE), in particular, as the SCLE adheres to both constructivist and socio-cultural learning theories of learning.

Theoretical and Conceptual Framework

I viewed the APSI workshop within an activity theory framework, as suggested by Engestrom (2015). Like Feldman and Weiss (2010), my intent in using activity theory is not to simply identify changes, but to understand changes occurring within in the context of the overall APSI. Using activity theory, participants and facilitator can be viewed as performing the roles of Subjects, using Tools, to produce the Object and Outcome that can be viewed from several levels (see Figure 4).

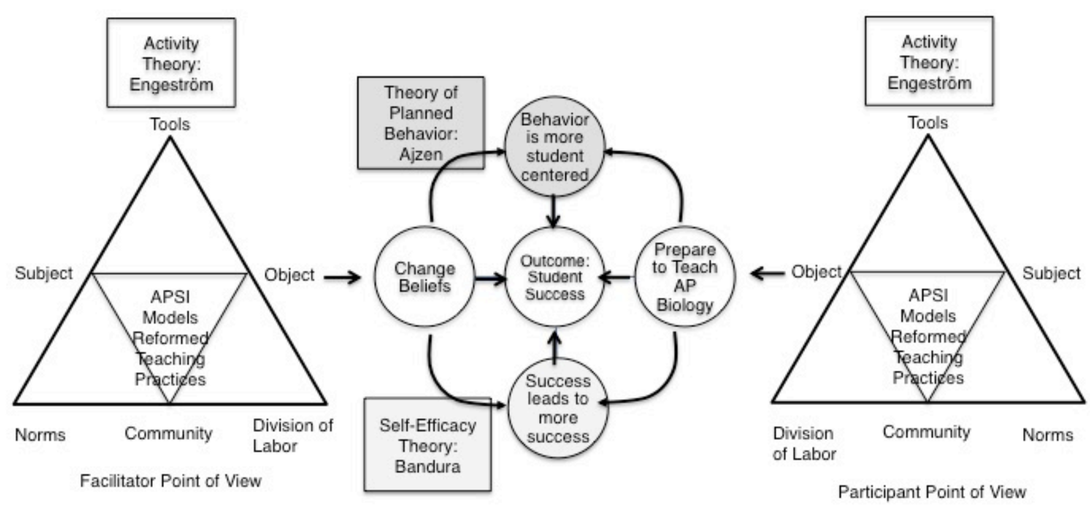

Figure 4. The APSI can be viewed as an activity system. This activity system, *Preparing to Teach AP Biology,* has two points of view or "voices," that of the facilitator and that of the participant. Though the Objects may at times be different, the Outcome is the same, greater student success. The theories involved in the intersections between the facilitator's Object of changing beliefs and the Outcome are shown. Adapted and modified from "Activity theory as a framework for designing constructivist learning environments," by D.H. Jonassen and L. Rohrer-Murphy, 1999, *Educational Technology: Research and Development, 47*, p.63.

Engeström (2000) explained the importance of point of view, or voice, in an activity system, thus allowing different actors to refocus and view the system from different vantages. Figure 4 indicates, for example, that facilitators and participants see the Object and Outcome differently. The most obvious Object from the point of view of the teacher-participants is preparing to teach AP Biology, which eventually leads to the Outcome of AP credit for their students. As the facilitator, my Object included the participants' Object plus an additional Object, increased reformed beliefs and improved self-efficacy. Our Objects both lead to the same Outcome, better student success. By changing reform beliefs, meaning that a teacher holds more reformed beliefs, we can anticipate the teachers will be more student-centered, which can be predicted with consideration of the theory of planned behavior (Ajzen, 2005). Improving self-efficacy will lead to more confident teachers. Teachers with higher self-efficacy, therefore, would have better student performance; their mastery performances will continue to increase their self-efficacy (Bandura, 1977). Activity theory involves interactions within a Community and its related Norms and Division of Labor. The APSI builds a Community of teachers from different backgrounds. The APSI possesses Norms and Division of Labor that develop as Community members (participants and facilitators) interact. The use of a variety of active learning strategies associated with reform, including inquiry laboratory experiences and integrated mathematics and science lessons, can be viewed as Tools within the activity system framework that are used to facilitate the creation of the Object and their transformation into the Outcome.

Figure 4 connects various concepts and theories involved in this study. The triangles represent Engeström's activity theory (Bourke et al., 2013) for the activities within a week-long APSI. Two triangles represent the workshop from two points of view, my view as a facilitator and my participants' view from their frame of reference. Regardless of our point of view, we are the Subjects and we make up the Community with its Division of Labor and Norms.

I aspired in my study to confirm and formalize my beliefs about practice. I wanted to investigate the effects of student-centered active learning (i.e., the activity system) on increasing teachers' levels of self-efficacy and reformed beliefs (i.e., the Object). I tied beliefs and attitudes to behavior in the theory of reasoned action (Ajzen & Fishbein, 1980) and the theory of planned behavior (Ajzen, 2005) and anticipated that a change in teachers' beliefs would predict a likely change in teachers' behavior toward more reformed teaching. Reformed teaching behaviors will lead to improved student performance, thus concurring with researchers who have found teaching in a more reformed, active way to improve student performance (Freeman et al., 2014), increase student retention (Haak, HilleRisLambers, Freeman, & Pitre, 2011), and reduce the achievement gap for underrepresented groups (Haak et al., 2011).

Research Gap

Measuring science teaching and learning beliefs is critical for progress towards reforms to occur (Sampson et al., 2013). What are the beliefs of teachers who are in the beginning stages of teaching AP Biology? I have found no studies that provide evidence of teacher learning from an APSI in biology. Actually, very few studies have focused on

AP Biology professional development. Despite current reforms in AP Biology, which should be driving research, I found no studies examining the effect of AP Biology professional development at the workshop level. Research has not been a priority at all, even in light of the massive attempts to retrain all the AP Biology consultants nationwide to deliver student-centered, reformed-based APSIs. Reports from the College Board exist that connect the amount of professional development to student achievement (Laitusis, 2012), describe AP teacher practices (Paek, Braun, Trapani, Ponte, & Powers, 2007), and characterize attitudes about an APSI experience (Godfrey, 2009). These are broad, large grained reports that provide useful information, but do not analyze at the biology workshop level. Van Driel, Meirink, van Veen, and Zwart (2012) noted a gap in the science professional development research regarding the role and preparation of the facilitator of the professional development. While noting that the researcher and facilitator are often one and the same, this researcher suggested a need for more transparency on the expertise of this key player. In spite of the lack of research, national reform documents stress the need for professional development in science (National Research Council, 1996; Burton & Frazier, 2012). We need to know whether professional development is successful. My current position as an APSI provider provided me with a unique opportunity to make contributions to what research says about preparing AP Biology teachers to implement reform-based practices in their classrooms.

The Abbreviated History of Science Education Reform

References to "reform" in education are common. To be more meaningful, however, some unpacking of the term is needed. In this section I discuss the history of reforms in science education, what is meant by reform in terms of science education, and where we are today in regard to these reforms.

Early Reform in Science Education

K-12 science education has been the subject of repeated reform efforts (DeBoer, 2000). World War II brought an awareness of the dual nature of science with its possibility of both great gain and great harm. The United States needed citizens who could participate meaningfully in discussion and decisions regarding scientific concerns that affected society. The launch of Sputnik in 1957 brought about a reactionary change resulting in scientists developing rigorous science courses that used inquiry pedagogy. Early 1960s courses were modeled after the work of scientists in order to develop future scientists. The 1970s and 1980s saw a controversial emphasis on science, technology, and society (STS) issues that resulted in a curriculum developed around social problems rather than scientific content. This was the first time content took a second place position.

The publication of *A Nation at Risk* (Gardner, 1983) represented a turning point in the history of educational reform. This document served as a wake up call to the American people when it informed them of a decline in performance of United States high school students:

> If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war (Gardner, 1983, p. 5).

This report recommended increases in high school graduation requirements and college entrance requirements, and the development of subject standards. *A Nation at Risk* was the push that led to the current reform effort.

The American Association for the Advancement of Science picked up the call with the publication of *Science for All Americans* (1990). This extremely influential work outlined goals for science education literacy for high school graduates. A companion work, *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993) developed end point guidance for four grade bands ending at second, fifth, eighth, and twelfth grades. Attainment of these guideposts would ensure scientifically literate graduates for the adult world, a world that included science, mathematics, and technology.

Shortly after *Science for All Americans* (American Association for the Advancement of Science, 1990) was published, the National Academy of Science began the development of national standards for the United States government (DeBoer, 2000). In 1996 the *National Science Education Standards* (NSES; National Research Council) were produced, providing content standards with the overarching goal the development of a "scientifically literate society" (p. 11). Goals for students included: (1) personal fulfillment from the study of the natural world, (2) ability to use the techniques of science for personal decisions, (3) ability to engage in reasoned discourse about societal problems related to science, and (4) improved economic conditions both personally and as a society.

Effect of Reforms on Science Education

The reform documents ushered in a constructivist view of science. In constructivist theory, students build upon existing knowledge (Vygotsky, 1978). We see the change in philosophy in this quote from the *National Science Education Standards*, "The Standards rest on the premise that science is an active process. Learning science is something that students do, not something that is done to them" (National Research Council, 1996, p. 2). In order to meet the new standards, students were expected to make connections both within the sciences and with other subjects including mathematics and technology. Active learning and inquiry were elevated in importance as desirable pedagogies with students mentally engaged and socially connected through collaborative efforts. An emphasis on equity was introduced; these standards were for all students.

The reform documents have informed many elaborations and expansions that include *How People Learn: Brain, Mind, Experience and School* (Bransford, Brown, & Cocking, 2000) which applies information from cognitive science to teaching and learning. Bransford et al. (2000) synthesized findings from a number of fields in psychology and pedagogy to create four perspectives with which a teacher must create an effective learning environment. The teacher must view his/her planning, implementation, and assessment of teaching and learning from learner-centered, knowledge-centered, assessment-centered and community-centered perspectives.

Status of Reform Today

Nearly twenty years after the reforms began, *A Framework for K-12 Science Education* (National Research Council, 2012) provided an updated framework for the development of new science standards. *Next Generation Science Standards* (NGSS Lead States, 2013) were created from this framework. These new documents are built upon the foundation provided by *Science for All Americans* (American Association for the Advancement of Science, 1990), *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993) and the *National Science Education Standards* (National Research Council, 1996). One document used in this update to the standards is particularly relevant to the topic of my proposed research, *Science: College Board Standards for College Success* (The College Board, 2009). This document veered from the goal of *Science for All Americans*, that of science literacy for all, to a more specific coal of college readiness for college-bound students. The philosophy of preparing students in high school for college success is consistent with calls for retention of STEM student in the leaky career pipeline. To guide their work the committee first agreed on the meaning of knowing science as:

> Knowing science requires individuals to integrate a complex structure of many types of knowledge. These knowledge types include the following tasks: explain and predict phenomena, interpret situations, solve problems and participate productively in science practice and discourse. (The College Board, 2009, p. xvi)

They relied on concepts from the learning sciences summarized in volumes like *How People Learn: Brain, Mind, Experience and School* (Bransford et al., 2000).

In spite of the release of ever-increasing numbers of documents and national reports related to science reform, the word is slow to reach K-12 teachers (Burton & Frazier, 2012). The reforms that have made inroads into K-12 schools are those that are easier to implement and cognitively less difficult (Banilower et al., 2013). Banilower et al. (2013) reported a high percentage of teachers made their objectives clear, a simple reform, but few elicited prior knowledge to uncover misconceptions, or gave time for metacognitive reflective writing. A disconnect exists between what teachers do and recommended strategies in the reform documents which include eliciting students' prior knowledge to build upon their knowledge base and leading them to appreciate the place of inquiry in science instruction (Banilower, Heck, & Weiss, 2007). The reforms expand the teachers' role to include modeling, exploring and discussing ideas in science. These reforms do not represent the traditional approach many science teachers experienced in their science education. The AP Science redesign is one program that is focused on these cognitively difficult curricular changes consistent with reform.

The Intersection of Reform and the AP Biology Redesign

The committee creating the *Standards for College Success* (The College Board, 2009) used the AP science courses as their end point. The standards focus on the "big ideas" (The College Board, 2009, p. xvii) in science, those "overarching principles and core ideas that have explanatory power within and across science disciplines" (The College Board, 2009, p. xvii). "Big idea" will return as an organizing principal in the AP Biology redesign (The College Board, 2013), which was performed by Committees of experts working under the National Science Foundation (The College Board, 2009, p. xvii).

In 2013 the College Board rolled out the first student exam for a redesigned science course. AP Biology was the first science course redesigned, but AP Chemistry and AP Physics quickly followed. The AP science redesign builds from the recommendations for major reforms in science education as follows:

The revised AP® Biology course:

- Moves "from a traditional 'content coverage' model of instruction to one that focuses on enduring, conceptual understandings and the content that supports them" (The College Board, 2011, p. 1).
- Enables "students to spend less time on factual recall and more time on inquiry-based learning of essential concepts" (The College Board, 2011, p. 1).
- Develops in students "advanced inquiry and reasoning skills, such as designing a plan for collecting data, applying mathematical routines, and connecting concepts in and across domains" (The College Board, 2011, p. 1).

The *AP Biology Curriculum Framework* (The College Board, 2011) is the standards document for the redesigned course. The new course is one favoring a focus on depth over the breadth of information, thus reducing the previously overwhelming amount of material found in the AP Biology curriculum. The teaching model focuses on conceptual understandings. Student Outcome from a course taught with the new curriculum framework includes the development of "advanced inquiry and reasoning skills" (2011, p. 1).

The AP Biology redesign was necessary but ambitious. Leaders in the field of biology like Mark Little, President of the National Association of Biology Teachers at the time, were excited about the reform based changes to the course and were prepared to "embrace the change" (Little, 2013. p. 308). Little claimed the changes were steered by higher education based on a need to be in alignment with two-semester college courses. I question whether this was the only driving factor, as the reforms left the AP Biology program in a conceptually more rigorous position than some college programs. Rather, I feel the thrust of AP Biology redesign is tied to reforms in the *National Science Education Standards* (National Research Council, 1996) through its connection with *Science for All Americans* (American Association for the Advancement of Science, 1990). Wood (2009b) remarked on the AP Biology curriculum changes with, "An intriguing possible outcome of the AP revision is that it may eventually drive much-needed change in college and university teaching of introductory biology" (p. 1638). Consider the view of D'Avanzo (2013) who discussed *Vision and Change in Undergraduate Biology Education: A Call to Action* (American Association for the Advancement of Science, 2011). D'Avanzo noted the document provided a vision of change for transformation of undergraduate biology education, but lacked needed evidence-based models. She further claimed reform is hard and questioned whether we know how to reform science teaching. This concern from the academy brings into question Little's declaration about source of the reforms. Rather than the top down it may have been from the bottom up.

Regardless of the direction of the reforms, massive professional development offerings would have to occur to realize the needed changes. Wood (2009b) reviewed the curriculum changes and questioned the ability of the College Board to provide training for the number of AP Biology teachers involved due the complexities of the reforms. The training would need to include student-centered learning, inquiry, and an increased use of mathematical reasoning, particularly statistics.

Professional Development and Science Reform

Connecting Professional Development to Reform

Effective professional development connects the national standards with science teaching (Banilower et al., 2007; National Research Council, 1996). Reform in education requires several layers of change, especially in science (National Research Council, 1996), which can include college science teaching. For example, AP Biology is taught in high school as the equivalent of college biology (Wood, 2009b). Successful AP exam performance following completion of the high school course may translate into college credit. Research about biology education reform at the high school and college levels, while dependent on context, is valid and can inform both educational levels. *Vision and Change in Undergraduate Biology Education: A Call for Action* (American Association for the Advancement of Science, 2011) is an undergraduate biology reform document. In this document the undergraduate student-centered classrooms is described as “interactive, inquiry driven, cooperative, collaborative and relevant” (p. 22). The document provides a list of the core competencies for undergraduate biology:

> (1) Ability to apply the process of science, (2) Ability to use quantitative reasoning, (3) Ability to use modeling and simulation, and (4) Ability to tap into the interdisciplinary nature of science” (American Association for the Advancement of Science, 2011, p. 14).

Woodin, Carter, and Fletcher (2010) reviewed the key findings in *Vision and Change* and noted, “These recommendations mirror those for revision of Advanced Placement courses and exams” (p. 72).

The Need for Quality Professional Development

Teachers will need high quality effective professional development to prepare for learner-centered, reform-based teaching (Desimone, 2009). A common professional development framework follows this flow: increased teaching ability will lead to better instruction and this in turn will increase student performance (Banilower et al., 2007; Desimone, 2009). The key to successful reform of science in schools, including AP Biology, is the availability of teachers who have teaching skills consistent with the student-centered, conceptually rigorous changes (National Research Council, 2002). In order to maintain the quality of the AP Biology program, a considerable amount of professional development is needed (Klopfenstein, 2003). This is particularly true in light of the recent reforms. Even highly skilled teachers will need training to deliver recommended instructional practices (National Research Council, 2002).

What is Effective Science Professional Development?

Guskey and Yoon (2009) analyzed research to find elements of professional development associated with increased student learning. Out of nearly 1,300 potential studies, only nine met the criteria for inclusion in their "research synthesis" (Guskey & Yoon, 2009, p. 495). What an analysis of the data from these nine studies revealed, however, was illuminating and somewhat surprising. These researchers found that though workshops were often criticized as ineffective, every one of the nine studies that revealed a positive relationship between student learning and professional development involved a workshop or summer institute. The workshops involved active learning for participants, focused on research-based pedagogies, and made practices relevant to individual teaching situations. Guskey and Yoon also found the use of an outside expert for professional development was linked to increases in student performance. They found no evidence supporting school-based efforts (e.g., peer coaching, collaborative problem solving). The researchers did not rule out school-based efforts, however, due to small sample size. A duration time of 30 or more hours of professional development was found to be most effective, as was the professional development follow-up. The professional development activities they linked to student learning were not specifically 'best practices," however. The professional development activities, rather, were those determined by the needs of the workshop participants. Training that was most effective focused specifically on classroom needs in relation to content and pedagogy.

What is effective science and mathematics professional development according to participating teachers and facilitators? Rogers et al. (2007) asked 72 teachers and 24 facilitators this question. The results of this qualitative study revealed a shared view of many features of effective professional development. Effective professional development was found to be that which: (1) was relevant in the classroom, (2) featured teachers as learners, and (3) valued networking. The facilitators agreed on one additional characteristic, the importance of teacher knowledge. Rogers et al. compared these characteristics identified by the teachers and facilitators to the qualities of effective professional development found in the literature and noting similarity. However, the teachers and facilitators did not mention three characteristics found in the literature. These were: (1) challenging teacher beliefs through transformative activities, (2) developing leadership within the teacher ranks, and (3) using student data for setting goals and to measure professional development success.

These two studies outlined features of professional development considered effective by teachers and facilitators (Rogers et al., 2007) and effective for students (Guskey & Yoon, 2009). Agreement on core competencies of professional development was the next step.

What Are the Core Competencies for Professional Development?

Desimone (2009) outlined a consensus for core competencies of professional development suggesting a conceptual framework that could be used as an evaluation guide for effective professional development. Professional development programs focusing on reform are often guided by components of these core competencies (Blank, delasAlas, & Council of Chief State School Officers, 2009; Guskey, 2003; Loucks-Horsley & National Institute for Science Education, 1996). Most of the current efforts in science professional development are designed around these reforms (Van Driel et al., 2012). Desimone's (2009) core competencies for effective professional development are: (1) content focus, (2) active learning, (3) coherence, (4) duration, and (5) collective participation.

Content focus. Effective professional development must focus on content, classroom practice with regard to relevant subject matter, and the pedagogical content knowledge that it entails (Guskey & Yoon, 2009; Van Driel et al., 2012). This core competency is considered to be the most important element of effective science professional development (Desimone, 2009). Project CRESST, *Enhancing Clinical Research Education for Science Students and Teachers* (McKeown, Abrams, Slattum, & Kirk, 2016), is an example of a professional development program that included inquiry-related content as a goal. This multi-year, multi-step professional development program, which included active participation and reflection by teacher participants and modeling by facilitators, resulted in significant positive increases in teacher participants' self-efficacy.

Duration. Research on the effects of the duration of professional development to change teacher behavior is inconsistent (Van Driel et al., 2012). Desimone (2009) suggested a 20-hour minimum for effective professional development. Supovitz and Turner (2000) found a relationship between the duration of professional development and the use of reformed practice with 80 hours or more linked to more inquiry and an investigative culture in the classroom. In terms of changing teachers' attitudes, a standards-based professional development with 80 or more hours produced teachers with better attitudes toward the reforms than teachers who participated less than 80 hours with the increase leveling off somewhere between 80 and 100 hours of professional development (Banilower et al., 2007). Regardless of the exact length, evidence from research can be used to support long-term professional development with related follow-up as compared to one-day events (Desimone, 2009; Guskey & Yoon, 2009). Furthermore, research related to the effects of professional development on student performance finds 30 or more hours to be effective (Guskey & Yoon, 2009).

Coherence. Professional development must be coherent, aligned with the relevant objectives and goals of the relevant organizations such as the school district and state (Desimone, 2009; Van Driel et al., 2012), and with other professional development activities in which teachers are involved (Windschitl, 2008). Professional development standard D in the *National Science Education Standards* (National Research Council, 1996) states:

> Quality preservice and inservice programs are characterized by clear shared goals based on a vision of science learning, teaching, and teacher development congruent with the *National Science Education Standards.* (p. 70)

Collective participation. Collaboration is an important component in successful professional development. Collaborative practice (Desimone, 2009) or collaborative learning (Van Driel et al., 2012) refers to the social nature of effective professional development events. Teachers reported working with their peers as critical in improving their content skills (Borko, 2004). Social arrangements involving the principles of clarification and illumination through conversation were found to be successful for students and teachers (Haak et al., 2011; Van Driel et al., 2012).

Two-hundred and forty-one science and math teachers were involved in a professional development study in Missouri (Chval, Abell, Pereja, Musikul, & Ritzka, 2008) that investigated what teachers want out of professional development and found teachers wanted opportunities to interact with their peers, including those from other fields. For example, interactions might include time for math and science teachers to interact. Teachers had a clear interest in collaborating with others with similar interests who were willing to share what they know. Using the information from the Chval et al. (2008) study, a workshop was set-up for 74 biology and geometry teachers engaged in a STEM-focused professional development in Florida. The teachers identified collaboration with their peers as the most important feature of the professional development (Beaudoin, Johnston, Jones, & Waggett, 2013).

Active learning. Active learning, a big umbrella that includes inquiry and integration, has a central place in professional development in science teaching. Active learning has been defined as "any activity in which every student must think, create, or solve a problem" (Graham, Fredrick, Byars-Winston, Hunter, & Handelsman, 2013 p. 1456). As I believe active learning to be the most critical of the core competencies for professional development, I have included a much more extensive discussion in the next section.

Active Learning: A Core Professional Development Competency

The bones of active learning emerged from the reform documents. An often-quoted phrase in the *National Science Education Standards* foreshadowed a monumental change in the way we think of science teaching and learning, “Learning science is something students do, not something that is done to them” (National Research Council, 1996, p. 2). Felder and Brent (2009) developed a definition that focused on the classroom: “Active learning is anything course related that all students in a course section are called upon to do other than simply watching, listening, and taking notes” (p. 2). A clear emphasis was focused on “any” activity, and “all” or “every” student.

The Theoretical Basis of Active Learning

Explanations for why active learning works can be found in social constructivist theory (Vygotsky, 1978). Students construct their own knowledge through analysis of incoming information and replacement of existing pieces with new pieces offering a better fit. Active learning exercises are almost always social in nature, with student collaboration used to identify misconceptions and to begin replacement. Active learning strategies can be very simple to use. Commonly used active learning strategies are think-pair-share and multiple-choice questions answered with clickers followed by discussion (Felder & Brent, 2009). In *Scientific Teaching*, Handelsman, Miller, and Pfund (2007) include brainstorming, one-minute writing, sequencing, decision-making, concept mapping, and pre-post questioning as examples of active learning. They also included the use of case studies and problem based learning exercises. Most active learning strategies reveal prior understandings and misconceptions, providing students an opportunity to reorganize what they know.

Active Learning is Effective

Active learning is much more effective than traditional, lecture-based teaching in producing positive outcomes in science education. Freeman et al. (2014) commented that if active learning were an intervention in a medical trial it would be stopped. A large number of reports have outlined a range of benefits for learners. For example, active leaning improved student performance (Armbruster, Patel, Johnson, & Weiss, 2009; Freeman et al., 2014; Haak et al., 2011; Wieman, 2014), increased conceptual gains (Udovic, Morris, Dickman, Postlethwait, & Wetherwax, 2002), increased problem solving ability (Hake, 1998), reduced gender bias (Freeman et al., 2014), and reduced the achievement gap (Haak et al., 2011).

Hake (1998) conducted a large-scale study of over 6000 United States physics students enrolled in high schools, community colleges, and universities. The primary instrument used to measure change was the Force Concept Inventory (FCI). The difference in FCI scores between traditional sections and interactive sections was highly significant. The average normalized gains were more than twice as large for the interactive sections. Active learning resulted in an improved student outcome in physics. Building on the reported success of active learning with physics students, Udovic et al. (2002) conducted a study in undergraduate introductory biology to address concerns regarding the traditional course's failure to provide lasting skills and knowledge. This University of Oregon study of Workshop Biology examined student attitudes and conceptual gains from a course structure built around inquiry, scientific misconception, and practical context. Conceptual question items were scored much higher for the workshop group than the traditional group ($p < 0.0001$). Over the course of the study, the successful active learning strategies from the experimental biology workshop course were used in sections that met twice a week for 90 minutes each. These "hybrid" sections also experienced increased success in student performance when compared to the traditional sections. Success did not depend on the extended time (300 minutes a week) devoted to the experimental workshop course, which improves the prospect of scalability. Active learning did not simply improve outcomes in physics; it worked in biology as well, and the gains appeared scalable to traditional scheduling formats.

Knight and Wood (2005) compared traditional and interactive sections of large, upper-level developmental biology courses over three semesters to examine the effects of the addition of student-centered interactive components to the course. During the fall semester of 2003 the traditional course was taught. The fall 2003 traditional (lecture-based) course was compared to a spring 2004 interactive course and repeated with a comparison to a spring 2005 interactive course. The interactive courses featured less lecture and more student-centered activities including in class cooperative problem solving with formative assessment. A pretest and posttest design was used with both quantitative and qualitative items. Significantly higher learning gains, including better conceptual understanding, were found in the interactive sections ($p = 0.001$ for a two-tailed t-test). Homework responses were compared between groups and the students working in collaborative groups performed much better than their peers in traditional sections. One less successful component, grading on a curve, was not a good fit for this collaborative model and was removed for the 2005 group. They noted the active learning strategies changed the entire purpose of the class from transmission of biological knowledge to its application. Components of successful active learning included identifying misconceptions and a direct connection to the reforms in science teaching and learning. Knight and Wood found the use of interactive devices or "clickers" invaluable as instructors uncovered student misconceptions, a strategy that we see employed in many studies.

Freeman et al. (2007) also looked at the use of clickers as part of their study of prescribed (graded) active learning techniques. Freeman et al. were concerned not only with global loss of students from the college and career pipeline due to failure, but also specifically with loss of underrepresented minorities and economically disadvantaged students. Their 2005 study examined four sections of beginning biology in a three-course majors sequence compared to a similar 2003 class taught in a Socratic seminar style. The spring 2005 intervention involved four combinations of two strategies, clicker questions (graded) versus response cards (participation), in combination with on-line individual essay writing and evaluation versus in-person group essay writing and evaluation. The evaluations were completed for a peers' paper using an instructor provided rubric. The failure rate dropped significantly ($p = 0.049$, Fisher's exact test, one-tailed) between the traditional lecture course (15.6%) and the active learning sections (10.9%) and the course performance on a common midterm was better (*t*-test, $p < 0.001$). No statistically significant difference was found overall among students due to the structure of the practice essay (group or individual) or the type of in-class responses (private, graded, clicker answers or public, ungraded, card responses). However, the clicker group had better attendance ($p < 0.0001$), a variable that had a positive correlation to final course grade. In the fall of 2005, the in-class participation portion was isolated for study. Students were enrolled in a graded clicker class or a participation section using response cards. Students in the sections where clicker questions were graded experienced increased performance on clicker questions, increased attendance and reduced failure rate associated with increased attendance.

Freeman et al. (2014) contributed enormously to the research on active learning in a large-scale meta-analysis of 225 studies that compared active learning to traditional methods. This study not only retired any questions about the positive value of active learning, but also essentially reported that active learning is so much better than traditional lecture methods that if it were a medical trial it would be "stopped for benefit" (p. 8413). They developed a working definition of active learning by collecting definitions from participants at active learning workshops throughout the United States and Canada. The working definition was established as:

> Active learning engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work. (Freeman et al., 2014, p. 8414)

Effects of active learning on assessment were examined in 158 studies; and 67 more were analyzed for effect on failure rate. The studies examined a variety of active learning strategies including cooperative class activities, clickers, problem based learning activities, and studio classrooms. Percentages of class time spent on active learning activities ranged from 10-100%. These researchers reported active learning increased student performance on assessments in all STEM classes with an overall effect size, a “weighted standardized mean difference” (p. 8410), of 0.47. The increased performance was higher on concept inventories than course exams. The effect was more pronounced in small classes (less than 50 students) rather than large classes. Udovic et al (2002) also reported the increased benefit of active learning in smaller settings. The meta-analysis by Freeman et al. concluded that students were one and a half times more likely to pass a course that used active learning, and, in fact, “Lecturing increases failure rate by 55%” (Freeman et al., 2014, p. 8412). The author’s implications of this study included a recommendation that the research community move to second-generation studies on active learning.

In second-generation work, Connell, Donavan and Chambers (2016) examined the amount of active learning in undergraduate biology classes, and associated higher levels of student-centered activity with improved student performance [even more than moderate levels]. First attempts at second-generation work have a long way to go. However, as Freeman (2014) suggested, no further first generation comparisons with traditional lecture are necessary.

Promising professional development programs have focused on active learning strategies. Trautmann and Makinster (2005) reported on the Cornell Science Inquiry Partnership (CSIP), a specific program within the NSF Graduate Teaching in K-12 (GK-

12) Education program, as a successful modeling that increased inquiry-based teaching by pairing science graduate students with classroom teachers. Teachers in this model had classroom support that helped them persevere in the teaching of inquiry through obstacles. Four barriers to inquiry teaching were identified in this qualitative study: concerns over content coverage (including testing pressures), concerns over the time needed, student issues such as readiness and behavior, and fear of the unknown as it relates to work with student. The program helped the teachers grow and embrace inquiry but one teacher described teaching with the inquiry process as "a leap of faith" (Trautmann & Makinster, 2005, p. 9).

Active Learning Benefits Underrepresented Groups

One of the most important benefits to active learning is the effect it has on underrepresented groups in science. Active learning has been found to reduce gender bias (Freeman et al., 2014). Haak et al. (2011) found active learning lowered the achievement gap and reduced attrition in science majors.

Student Reaction to Active Learning

Student attitudes about active learning are important for college and university professors who rely on positive student evaluations for retention and promotion. We find conflicting reports on student attitudes about active learning. Student satisfaction was analyzed before and after implementation of active learning strategies in large biology classes at a Washington DC university (Armbruster et al., 2009). This study used both quantitative, Likert scale data and open-ended questions that were coded and categorized. The number of positive student comments in the course assessments rose from 65% in the comparison, traditional year, to 81 % then 89% in the following two years which used a variety of active learning strategies. The areas of negative comments shifted from lecture to problems with group work. This could be a result of the change to the classes themselves, or as Felder and Brent (2009) said, "Classes are much more lively and enjoyable" (p. 5). Others studies find attitudes about active learning mixed, with students valuing the learning, but complaining about the amount of work (Udovic et al., 2002). This concern was recognized (Felder & Brent; Wood, 2009a) and teachers were advised to deal with it explicitly by providing an explanation of the benefits of the pedagogy to student learning. Felder (2007) tried to provide support to teachers who suffered student discontent by providing some sample explanations that could be used with students. A recent study (Connell et al., 2016) reported findings similar to the earlier work, students were largely very satisfied but one-third still preferred lecture. Presumably these students have experienced student-centered instruction, so being unfamiliar does not seem to be the likely cause. The fact that active learning helped students do better, didn't mean they necessarily enjoyed the extra work involved.

Issues for Instructors

The studies discussed so far clearly showed the benefits of active learning in terms of improved student performance, retention in STEM, and reducing the achievement gap. In spite of overwhelming evidence, traditional lecture and other pre-reform strategies are being used by many teachers (Banilower et al., 2013).

Though it has been over nearly thirty years since the publication of *Science for All Americans* (American Association for the Advancement of Science, 1990) we are still working on reforms. *A Framework for K-12 Science Education* (National Research Council, 2012), and the *Next Generation Science Standards* (NGSS Lead States, 2013), have kept the need for student-centered constructivist learning based on high standards relevant. A look back shows reformed ideas have a long history. History provides an example for successful teaching that addressed the, then future, reforms. Sam Postlethwait successfully used reformed methods 50 years ago while teaching botany at Purdue (Pelaez, Anderson, & Postlewait, 2014). His works showed reform based active learning worked then and current work shows it works now.

If science education reforms are to make more than partial inroads into all science classrooms, there must be scalable systems available to train teachers in a way that analyzes their beliefs about reforms and self-efficacy and provides a map to change. This system should bring about positive change in these beliefs leading to teachers' increasing behaviors consistent with reforms.

Connection to the Professional Development

Active learning works and it works for all students as extensively supported above. To look at this through another lens we can ask, what science teaching methods lead to effective science teaching as evidenced by better student outcomes? Scott et al. (2005) performed a meta-analysis of research studies in science that used teaching strategy as the independent variable and student learning as the dependent variable. The teaching strategies were grouped into one of ten categories. Effect sizes were calculated for 62 studies that fit the study criteria.

I first noticed the similarity of the strategies under review to the strategies under the umbrella of active learning and noticed the considerable overlap, with only two of the ten not in my operational definition of active learning. It was interesting that of the two, the category of direct instruction was not found in any of the included studies and the second, enhanced materials strategies, was lowest ranked for effect size (see Table 2). The remainder of the list offers teachers a strong recommendation for teaching strategies that not only improve student learning, but also are consistent with a reform oriented, student-centered, constructivist teaching strategy.

Table 2

Ranking of Teaching Strategies

Strategies	Effect Size	Rank
Enhanced Context Strategies	1.4783	1
Collaborative Learning Strategies	.9580	2
Questioning Strategies	.7395	3
Inquiry Strategies	.6546	4
Manipulation Strategies	.5729	5
Testing Strategies	.5052	6
Instructional Technology Strategies	.4840	7
Enhanced Materials Strategies	.2908	8

Note. Adapted from " Meta-Analysis of National Research Regarding Science Teaching," by T. P. Scott, H. Tolson, C. Schroeder, Y. Lee, T. Huang, X. Hu, and A. Bentz, 2005, Prepared for Texas Science Initiative of the Texas Education Agency, Shirley Neeley, Ed. D., Commissioner of Education, p. 28.

Beliefs and Behavior

Teachers bring reforms to the classroom through their behaviors, behaviors that are tied to the teachers' beliefs (Ajzen & Fishbein, 1980; Bandura, 1977). In this section, I will discuss two types of teaching beliefs: (1) beliefs about science reform and (2) beliefs about self-efficacy. I will also review instruments for measuring these beliefs, and outline theoretical foundations that support their use.

Teachers hold beliefs about science reforms, and these beliefs can be measured. These beliefs reflect information that a person holds about an idea, in this case reforms (Fishbein & Ajzen, 1975). I will measure beliefs about reform using the *Beliefs about Reformed Science Teaching and Learning Instrument* (BARSTL; Sampson et al., 2013). Teacher self-efficacy beliefs defined as: "teachers' evaluation of their abilities to bring about positive student change" (Gibson & Dembo, 1984, p. 570) is another construct that can be measured and for this I will use the *Teachers' Efficacy Beliefs System-Self Form* (TEBS-Self; Dellinger et al., 2008). Beliefs are tied to behavior using the theory of planned behavior (Ajzen, 2005) so beliefs provide a way to predict teacher behavior and measure change.

Beliefs About Reformed Science Teaching and Learning

Sampson et al. (2013) developed the questionnaire to provide a valid and reliable method of measuring teacher beliefs about science reform. The purpose of the instrument was to measure alignment of science teachers' beliefs with science education reform. The reform ideas used for the items were taken from the major national reform documents, *National Science Education Standards* (National Research Council, 1996) and the *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993). The final instrument contained four subscales and thirty-two statements. Each statement could be placed at one or the other end of a continuum representing traditional to reformed beliefs in science teaching and learning. Using the reform literature, the instrument developers used a content matrix to "define the content for the BARSTL in terms of the reformed beliefs construct" (Sampson et al., 2013, p. 6). This matrix is reproduced in Table 3. The subscales were: (1) *How people learn about science* (HPL), (2) *Lesson design and implementation* (LDI), (3) *Characteristics of teachers and the learning environment* (CLE*)*, and (4) *The nature of the science curriculum (NOS)*. Respondents chose one of four responses, indicating their level of agreement with each statement. Developers performed multiple rounds of screening for the final instrument using experts in science reform who judged the final instrument to be valid for both content and the construct "reformed beliefs about science education" (Sampson et al., 2013, p. 6). The instrument was piloted in a university in the southwest United States with 146 pre-service elementary science education students. Internal consistency was measured with a split-half coefficient and coefficient alpha and found to be satisfactory. Belief teachers' hold about the construct "reformed beliefs about science education" (Sampson et al., 2013, p. 6) is different from belief regarding their ability to deliver in the classroom. For this I must turn to a second instrument.

The TEBS-Self

Self-efficacy is a person's belief in their ability to control an event in their life. Bandura developed the construct of self-efficacy in his 1977 article *Self-efficacy: Toward a*

Unifying Theory of Behavior Change. Bandura used a triangular model to explain the relationship between three factor involved in self-efficacy (Frager & Fadiman, 2002). These three factors affect one another, so a successful behavior can make a person feel more confident, in other words it changes a person's internal environment. Bandura (1989) viewed self-efficacy as the most direct cause of human action and motivation. Self-efficacy can affect people's persistence and willingness to handle adversity. Individuals with higher self-efficacy will try harder at a particular task, and successive successful activities continue to increase that success (Bandura, 1977). Teachers with higher self-efficacy believe they can succeed in the classroom, and the more success they experience the more their self-efficacy increases.

Bandura (1977) conducted an experiment to test the hypothesis that one source of self-efficacy is socially mediated. Bandura tested snake phobic individuals in three groups. In the participant-modeling group (direct mastery) the subject worked with an individual who helped him/her handle a snake until he/she was able to do so on his/her own. In the second group the snake handling was modeled but the subject never handled it, and in the third group, the control, there was no interaction with snakes. Consistent with social learning theory experimental results showed self-efficacy to be at least partly socially mediated. The greatest increases in self-efficacy, for the ability to handle a snake, were found in the participant-modeling group. Several data points were collected over time and self-efficacy was plotted against the behavior that was approach to the threat (snake). Changes in self-efficacy were closely tied to changes in behavior.

Table 3

Dimensions of Traditional and Reformed Minded Beliefs for Each Subscale of the BARSTL

BARSTL Scales	Traditional Perspective	Reformed Perspective
How people learn about science	Compared with "blank slates." Learning is accumulation of information.	What students learn is influenced by their existing ideas. Learning is the modification of existing ideas.
Lesson design and implementation	Teacher-prescribed activities. Frontal teaching-telling and showing students. Relies heavily on textbooks and workbooks.	Student-directed learning. Relies heavily on student-developed investigations, manipulative materials, and primary sources of data.
Characteristics of teachers and the learning environment	The teacher acts as a dispenser of knowledge. Focus on independent work and learning by rote.	The teacher acts as facilitator, listener, and coach. Focus on learning together and valuing others ideas and ways of thinking.
The nature of the science curriculum	Focus on basic skills (foundations) Curriculum is fixed. Focus on breadth over depth.	Focus on conceptual understanding and the application of concepts. Curriculum is flexible, changes with student questions and interest. Focus on depth over breadth.

Note. Adapted from "Development and Initial Validation of the Beliefs About Reformed Science Teaching and Learning (BARSTL) Questionnaire" by V. Sampson, P. Enderle, and J. Grooms, 2013, *School Science and Mathematics, 113*(1), p. 6.

The *Teachers' Efficacy Beliefs System-Self Form* (TEBS-Self; Dellinger et al., 2008) follows in a long line of instruments designed to measure teacher efficacy (Tschannen-Moran & Woolfolk-Hoy, 2001). As teacher efficacy and teacher self-efficacy have been confused for some time, the TEBS-Self was developed as an instrument clarifying and separating these two terms and measuring teacher self-efficacy alone (Dellinger et al., 2008). Teacher efficacy has been defined as "teacher's beliefs regarding limits in the effectiveness of teaching, particularly in overcoming effects of external factors such as home environment and family background" (Soodak & Podell, 1993). Teacher self-efficacy is defined by Dellinger et al., (2008) as "teachers' individual beliefs about their own abilities to successfully perform specific teaching and learning tasks within the context of their own classroom" (p. 751). The distinction concerns control.

Dellinger et al. (2008) reported on the development of the TEBS-Self in a paper that analyzed three independent doctoral studies that involved a total of 2,373 K-6 teachers. These studies were completed in a variety of communities in the southern United States and involved different research questions. One doctoral student, Olivier, was studying professional learning communities and the role it played in teacher retention, another doctoral student, Bobbett, studied the relationship between self-efficacy and school effectiveness, and Dellinger, the third doctoral student, compared different types of efficacy. The instrument was piloted with different question stems, after which the team selected the term 'belief' for the instrument in alignment with self-efficacy theory. Following item selection, the 30-item surveys were subjected to principal component analysis and Varimax (Olivier and Bobbett) or non-orthogonal rotation (Dellinger). Bobbett and Dellinger identified four components and Olivier identified five. The authors explained about 60% of the variance, but not in exactly the same way. Common components were Accommodating Individual Differences (AID), and Classroom Management (CM). The three studies had similarities that connected the component Monitoring and Feedback for Learning with Communication/Clarification (CC). Two studies reported Higher Order Thinking Skills (HOTS), and one included

Motivation of students. The analysis determined the instrument was reliable and the assessment by 45 experts showed it to be reliable. Dellinger et al. compared the TEBS-Self to the original RAND study that measures efficacy rather than self-efficacy and found little relationship. Dellinger et al. (2013) concluded the instrument "could be used to evaluate the impact of professional development experiences designed to influence teachers' belief in their abilities and their subsequent behavior in the classroom" (p. 763). The instrument was reported to be suitable for modification and in need of more research to tighten the component structure. Dellinger et al. considered this instrument more "theoretically and psychometrically sound" (p. 763) than the Gibson and Dembo's *Teacher Efficacy Scale* (TES; Gibson & Dembo, 1984). Gibson and Dembo's TES has been a popular efficacy instrument beginning with its development in the mid 1980s (Tschannen-Moran & Woolfolk-Hoy, 2001). According to Tschannen-Moran and Woolfolk-Hoy (2001, p. 789), a problem with the TES for measuring self-efficacy has been found in studies that show inconsistencies, for example incorrect loading for the two factors 'personal teaching efficacy' (PTE) and 'general teaching efficacy' (GTE). Soodak and Podell (1993) used a shortened version of the TES (16 item) and found one of the items loaded on the opposite factor from Gibson and Dembo's loading, and one factor did not load on either factor using their criteria. I looked at the misloaded item and I wonder if the problem is more a problem with Soodak and Podell's data than with Gibson and Dembo's survey. The item in question says, "If a student in my class becomes disruptive and noisy, I feel assured that I know some techniques to redirect him/her quickly" (Soodak & Podell, 1993). I feel it is soundly within Gibson and Dembo's (1984) factor personal teaching efficacy.

Connecting Reform to Beliefs

National reform documents have emphasized the need for higher standards in science and describe the path to excellence as a road lined with high-quality professional development (National Research Council, 1996). Changing teacher beliefs is considered an important job of professional development (McKeown et al., 2016). The relationship between teacher beliefs and professional development has strong theoretical support in the theory of planned behavior as beliefs were directly tied to behavior (Ajzen & Fishbein, 1980).

Ajzen and Fishbein first developed the theory of reasoned action (TRA) to connect beliefs to behavior (Ajzen & Fishbein, 1980) in their 1975 book (Fishbein & Ajzen, 1975). The TRA was built with beliefs as its foundation, based on "the assumption that people think and act in more or less logical ways" (Ajzen, 2005, p. 29). They said, "Beliefs represent the information (a person) has about the object" (Fishbein & Ajzen, 1975, p. 12). Beliefs affect a persons' attitude toward a behavior, which affects the intention to perform the behavior, through his/her view of the consequences of the behavior. Another type of belief that is important in this early framework is normative beliefs, those beliefs concerning what other influential parties think about the behavior. Subjective norms result from the normative belief combined with a person's degree of desire to comply with normative beliefs. The early conceptual framework for the theory of reasoned action as presented by Fishbein and Ajzen (1975. p. 16) is reproduced in Figure 5.

The theory of reasoned action was expanded into the theory of planned behavior (Ajzen, 2005; Conner & Armitage, 1998), which adds the construct of perceived behavioral control to improve prediction of behavior (Ajzen, 2005; Conner & Armitage, 1998). Whereas the TRA describes events connected to behaviors that are under individuals' voluntary control, the theory of planned behavior adds an involuntary component (Ajzen, 2005). The theory of planned behavior considers three aspects that affect intention (followed by behavior), personal beliefs about a behavior, a person's views on how their social group feels about a behavior, and how much control an individual believed they have over a behavior. Perceived behavioral control is equivalent to self-efficacy (Ajzen, 2005) bringing us back to our second instrument, the TEBS-Self (Dellinger et al., 2008) and interacting with Bandura's theory of self-efficacy (Bandura, 1977). Bandura's theory was previously discussed in the section on the TEBS-Self. The theory of planned behavior is reproduced in Figure 6.

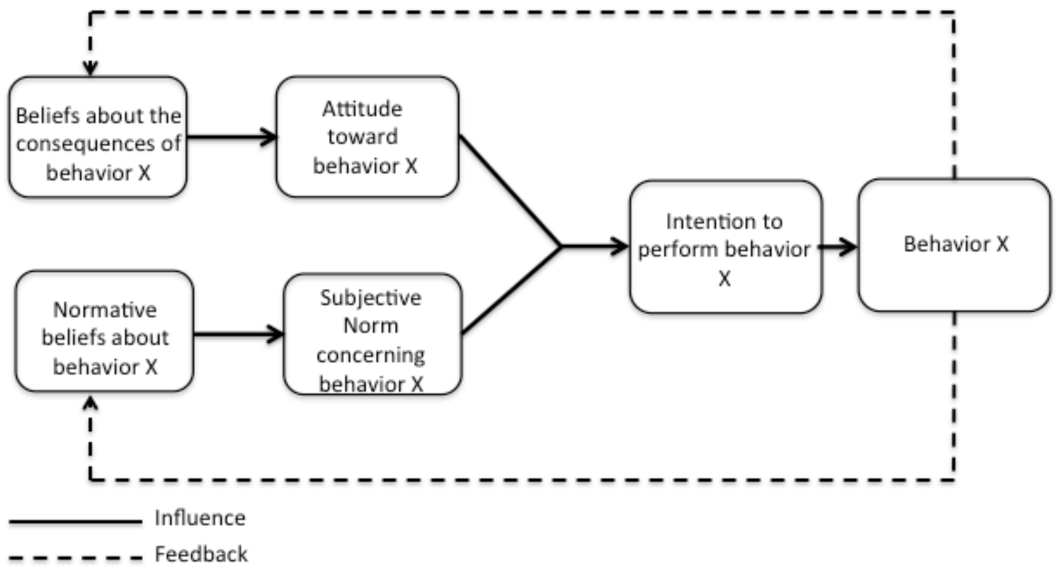

Figure 5. The theory of reasoned action. The graphic represents a conceptual framework used to predict intentions to perform a behavior. Adapted from *Beliefs, Attitudes, Intentions and Behavior* by M. Fishbein and I. Ajzen, 1975, Addison-Wesley, Reading, MA, p. 16.

The BARSTL measures behavioral and normative beliefs. The behavioral beliefs reflect a personal attitude about behavior. The normative belief reflects the person's view of how others feel about this behavior. The control beliefs will be measured with the TEBS-Self, an instrument that measures self-efficacy. As a result of mastery experiences, changes are predicted, in fact Bandura (1977) reported, "It is performance-based procedures that are proving to be most powerful for effecting psychological changes" (p. 191).

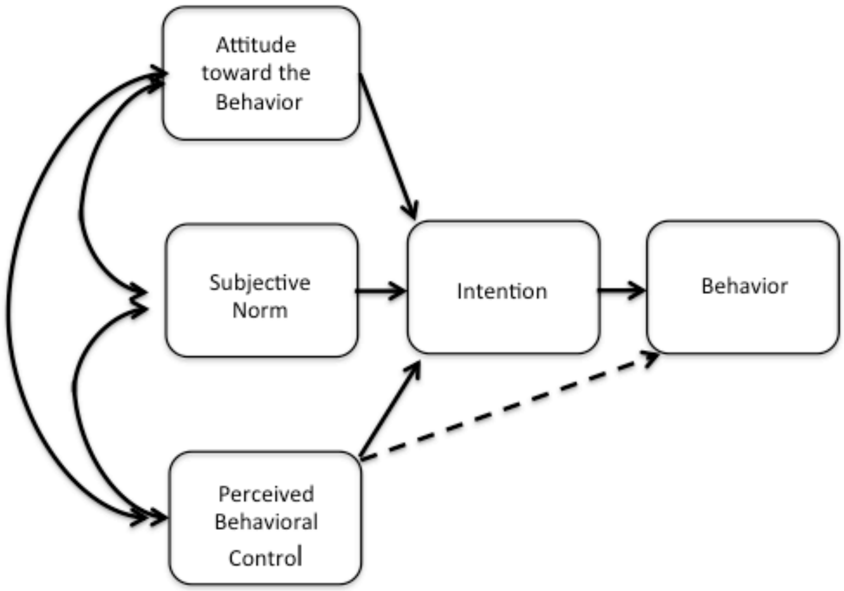

Figure 6. The theory of planned behavior. This graphic shows the addition of perceived behavioral control as a factor influencing intention to perform a behavior. Adapted from *Attitudes, Personality and Behavior* (Second ed.) by I. Ajzen, 2005, Open University Press, Berkshire, England. p. 118.

Research Needs

Statistics regarding the two instruments described above, the BARSTL (Sampson et al., 2013) and the TEBS-Self (Dellinger et al., 2008) indicate that both are valid and reliable for the population of K-6 teachers for whom they were developed. Authors for both instruments note the need for research on expanding the use of the instruments for different levels and contexts of teachers. Using these instruments with high school AP teachers is a move in that direction.

Van Driel et al. (2012) analyzed recent science professional development and noted a missing component linking professional development to the larger landscape. Since the AP Biology curriculum was changed to a reform-based model for the 2013 test

(The College Board, 2013), the professional development focus was changed. The findings from my dissertation work could be used to design a study of a random sample of AP Biology consultants to see if my results are representative of the entire consultant cohort.

CHAPTER III

METHODS

Study Context and Overview

I identified the problem under study in my role as an AP Biology® workshop facilitator for APSIs. In this role, I have worked with novice AP Biology teachers in summer institutes for several years. Recently, the goals of the AP Biology curriculum have changed to include new emphases unfamiliar to many classroom teachers. In light of these changes, I wanted to improve the summer professional development experiences provided in my workshops, specifically designed for new teachers of AP Biology, to more closely match the student-centered approach embedded in the new curriculum. My goal was to better meet the needs of workshop teachers in regard to their teaching self-efficacy beliefs and their reformed science teaching and learning beliefs. Appendix A provides a summary of the workshop curriculum I enacted for all workshop participants.

I employed a mixed methods research design, described by Creswell and Plano Clark (2011) as an embedded design approach, to implement this quality improvement study. Following this approach, I collected both qualitative and quantitative data to inform and direct modifications for a newly adapted professional development experience. I aligned my institute activities with Desimone's (2009) core competencies for effective professional development (content focus, active learning, coherence, duration, and collective participation). The focus of the modification was training teachers on student-centered learning (found in a reformed science approach) through the experience of student-centered learning to provide mastery, modeling, and other confidence building experiences. I chose case study methodology and an activity theory lens. Figure 7 is a schematic illustrating phases in the study, data collection emphases, and how I planned to merge qualitative and quantitative strands at a design level of the study.

Study Diagram

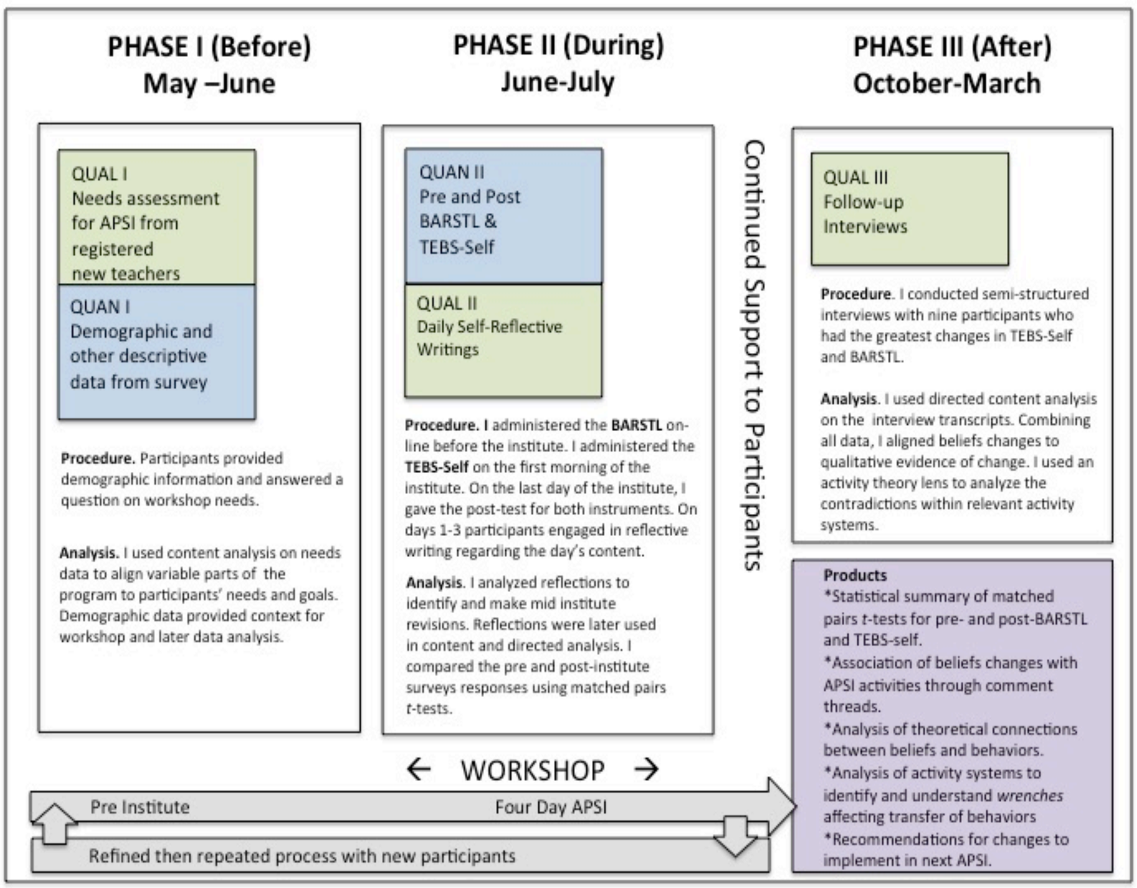

Figure 7. Three-phase, mixed methods, embedded study design. Phase I provided me with direction for the Phase II workshop. In Phase II, I collected reflections and survey data to measure changes in self-efficacy and reformed beliefs. In Phase III, I conducted interviews and sought to understand the beliefs changes.

Research Questions and Data Sources

I designed the mixed methods quality improvement study in three phases, with the hope of clarifying my understanding of the relationship between AP teachers' attendance in an APSI workshop with changes in their reformed science teaching and learning beliefs and changes in their self-efficacy. I wanted to see what classroom behavior changes followed attendance at the APSI and what tensions teachers see that prevent or reduce the transfer of reformed behaviors through beliefs changes to the classroom, as well as what helps with this transfer. The three-phase plan refers to activities before, during, and after the workshop. During this three-phase plan, the focus was on five research questions.

Research Questions

1. What are participants' particular goals and needs going into the APSI workshop?
2. How do participants' beliefs change in association with attendance at an APSI workshop?
3. How do I make sense of the changes in self-efficacy and reformed beliefs observed on participants' surveys after they attended the institute?
4. What were the participants' perceptions, beliefs, intentions, and behaviors about the institute workshop after returning to the classroom?
5. How can the activity theory lens assist in understanding issues surrounding classroom transfer?

Before the institute (Phase I), participants provided demographic information and their professional goals and needs for the upcoming institute. During the institute or shortly before (Phase II), participants completed two pre- and post-institute instruments designed to measure their beliefs. These instruments were the BARSTL (Sampson et al., 2013), and the TEBS-Self (Dellinger et al., 2008). Furthermore, I asked that participants answer four reflections questions each day for the first three days of the institute. I used these reflections formatively to adjust the daily program, and as a data source for analysis. I also took photographs of participants' laboratory posters for possible use as a data source, but I was unable to tie photographs to particular participants, which limited their usefulness. After the institute, I purposefully selected nine participants from those with the greatest change in their pre- and post-institute scores on the reformed beliefs or self-efficacy instruments. I interviewed participants from October to March during the following school year. I asked specific questions about their experiences in the workshop and what aspects of the workshop were of most value to them.

In addition to the three-phase mixed methods study design, I also used the qualitative data collected during all phases in a case study analysis. In the case study, I used an activity theory lens to assist me in understanding the transfer of student-centered, reformed behaviors from the professional development workshop to the participants' classrooms. I looked for contradictions or tensions that negatively affected this transfer. I used this analysis to guide future improvements to my summer institute workshop and to suggest factors that merit further study.

Data Sources

I initially collected seven data sources for this study. (As previously mentioned, the pictures of lab poster were not used because they could not be tied to individuals.) The relationship between research questions, the remaining six data sources, and relevant analyses are indicated in Table 4.

Participants

I invited teachers who enrolled in *AP Biology for New Teachers* workshops at one of two APSIs to participate in this study. I combined data from the two workshops to consider them as a single case study. I facilitated both institute workshops, which occurred in the western half of the United States, within a three-week time span during one summer. The institutes occurred several years after the administration of the first exams of the AP Biology redesign in 2013. (I withheld information about the exact year and location to protect the privacy of participants.) Forty-four teachers completed the entire four-day workshops and of those enrolled, forty workshop teachers agreed to participate in this study, yielding a 91% participation rate. The results of this study are based on the responses from the 40 consenting individuals, hereafter referred to as participants. All but one participant offered demographic information summarized in Tables 5 and 6.

Table 4

Research Questions With the Data Sources and Analytic Methods

Question	Data source	Analysis
1. What are participants' particular goals and needs going into the APSI workshop?	Pre-needs assessments and demographics sheet.	Conventional content analysis: Codes, categories, and themes.
2. How do participants' beliefs change in association with attendance at an APSI workshop?	BARSTL and TEBS-Self.	Matched pairs *t*-test of pre and post data.
3. How do I make sense of the changes in self-efficacy and reformed beliefs observed on participants' surveys after they attended the institute?	All data sources.	Directed content analysis: Codes based on theory. Combine with BARSTL and TEBS-SELF analysis
4. What were the participants' perceptions, beliefs, intentions, and behaviors about the institute workshop after returning to the classroom?	Interviews.	Directed content analysis: Codes based on theory.
5. How can the activity theory lens assist in understanding issues surrounding classroom transfer?	Pre-needs assessment, daily reflection sheets, teacher' interviews.	Conventional content analysis: Codes, categories, and themes.

Note. BARSTL is the Beliefs About Reformed Science Teaching and Learning instrument from "Development and Initial Validation of the Beliefs about Reformed Science Teaching and Learning (BARSTL) Questionnaire," by V. Sampson et al., 2013, *School Science and Mathematics, 113*(1). TEBS-Self is the Teaching Efficacy Beliefs System- Self Form instrument from "Measuring Teachers' Self-efficacy Beliefs: Development and use of the TEBS-self," by A. Dellinger et al., 2008, *Teaching and Teacher Education, 24.*

Table 5 summarizes information about the ages and years of teaching of participants. Compared to science teachers nationwide, this sample was younger and less experienced (Banilower et al., 2013). While the mean age of participants was 36.0 years, a little less than half of the participants were between the ages of 24-30. Nationally, only sixteen percent of teachers are 30 or younger. Participants in this study indicated a wide range of teaching experience (0-26 years). Over half of the participants reported five or fewer years of experience in teaching compared to 27% in the national sample. Figure 8 graphically represents this relationship.

Table 5

Participant Age and Teaching Experience in Years

Characteristic	Mean	Range	*SD*	*SEM*
Age	36.0	24-60	10.34	1.65
Teaching Experience	7.9	0-26	7.72	1.24

Note. Includes only participants (n = 39) who completed pre-institute demographics survey.

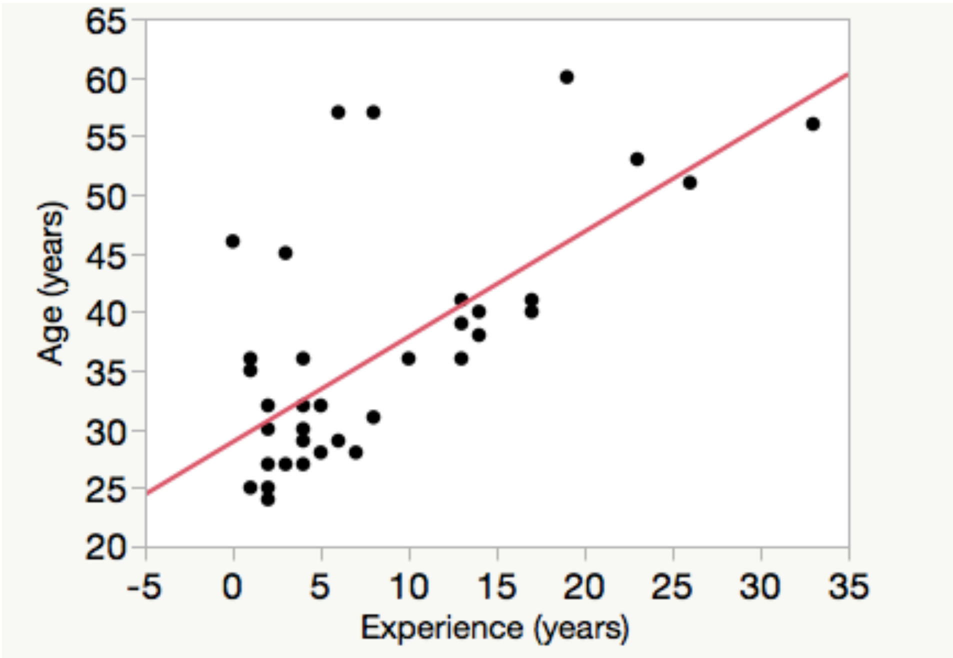

Figure 8. Bivariate fit of age (years) by teaching experience (years). This graph shows the clumping of participants in the lower left. Half of the participants were under 36 years old and had fewer than eight years of experience.

Table 6 includes other demographic information about participants. Note that over half of the participants were females (62%). The large majority of participants had a degree in science (74%) not including degrees in science education. A high percentage (82%) of the participants were new to the AP program. Participants taught in a wide variety of school with most (79%) being either urban or suburban. Furthermore, most (77%) came from public school, as compared with a lower percentage (15%) from private schools.

Table 6

Characteristics of Teacher Participants

Characteristic	N	%
Gender		
Female	24	62
Male	15	38
AP Teaching Experience		
None	32	82
1 year	5	13
3 years	2	5
School Location		
Rural	6	15
Suburban	18	46
Urban	13	33
Unknown	2	5
School Type		
Public	28	72
Public Charter	2	5
Private	6	15
Unknown	3	8
Degree in Science		
Yes	29	74
No	7	18
Unknown	3	8

Note. Includes only participants (n = 39) who completed pre-institute demographics survey. Due to rounding, percentage may not add up to 100.

Sampling design. All participants were involved in data collection activities in phases I and II. For Phase III, I purposefully selected nine participants on the basis of their BARSTL and TEBS-Self scores and requested that they participate further for the in-depth interview phase. To select interviewees, I ordered raw change scores in the BARSTL and the TEBS-Self and then invited participants with the largest score changes to be interviewed. I considered 16 individuals with the largest changes, eight per instrument. I began by inviting two participants per instrument at each site, and I continued down the list until up to five participants per site had accepted, with a goal of two to three participants, per instrument, per institute. The final number for interviews was nine individuals, six with large changes in the TEBS-Self, and three with large changes in the BARSTL.

Informed consent. Participating individuals provided voluntary consent to contribute their information to the dataset for this study. Individuals signing up for one of the two summer institutes received an e-mail containing information about the workshop, and an invitation to participate in this study. An electronic link took them to a consent form. Individuals who did not complete the consent form prior to the institute were able to provide consent at the institute. I have retained the consents in the form provided by the participants, either as hard copy or as a printout of the on-line form. On the first day of the institute, before completing the TEBS-Self (Dellinger et al., 2008), I reviewed a summary of the study project and consent form. The Texas A&M University Institutional Review Board (IRB) approved all documents before their distribution. Study participants were assured of privacy. Data in this study does not identify any specific location or individual; rather, psuedonyms and identifying numbers were used as needed.

Instruments and Procedures

Pre-Institute (Phase I): Demographics and Institute Goals

In Phase I preparatory to the institute, I collected both quantitative and qualitative data. The data source was a questionnaire distributed by email to APSI participants. Data included answers to demographic questions (see Appendix B), and one answer to this open-ended question completed by participants:

> Please tell me about your goals for our APSI. Are there any particular topics you want to see covered in the workshop? Information here helps me personalize this week to meet your needs.

I reviewed this input from participants before I made a final decision about the content for the biology session to ensure I was providing participants with the help they needed on the topics they wanted.

Pre-Post Instrument (Phase II): Surveys Measuring Reformed Beliefs and Self-Efficacy

As I reflected on the change of the goals of the AP Biology course to include new student-centered emphases unfamiliar to typical classroom teachers, I saw a need for improvement. I designed and implemented a quality improvement plan to collect information informing modifications in the summer institute to better meet the needs of institute workshop teachers. My own experiences as an AP teacher and experienced AP workshop facilitator led me to focus the redesign of my biology workshop on two basic understandings about effecting changes in teachers' classroom practices: (1) teachers' practices change when they believe that change is important, and (2) teachers' practices change when they believe they are able to make the change. With these understandings in mind, I refined the workshop to focus on teachers' beliefs about reformed practice and on their self-efficacy beliefs. To address reformed practices I designed the workshop with a student-centered pedagogy used as the participants' primary learning experience. This provided mastery experiences which are related to increases in self-efficacy. I chose two instruments with high reliability and validity to provide evidence that teachers' engagement in the APSI workshop was associated with positive changes in their beliefs about reformed practice and their own efficacy in enacting reformed practices in their own classroom. These two instruments were the Teachers' Efficacy Beliefs System-Self Form (TEBS-Self; Dellinger et al., 2008) and the Beliefs About Reformed Science Teaching and Learning (BARSTL; Sampson et al., 2013).

The BARSTL

Administration procedures. As part of Phase II (see Figure 7), I administered pre- and post-workshop surveys for two instruments, including the BARSTL (Sampson et al., 2013). In order to conserve time during the institute, I issued the BARSTL (Sampson et al., 2013) as an on-line form to participants the week before the institute. On the afternoon of the last day of the institute, I administered a paper version of the post-workshop BARSTL (Sampson et al., 2013). I administered the BARSTL (Sampson et al., 2013) in a pre-post institute design, to measure the teacher participants' alignment of their teaching beliefs with reforms in science teaching and learning. I used matched pairs *t*-tests to compare the pre- and post-institute differences in scores on these surveys.

Organization of the instrument. This 32-item instrument, composed of four subscales of eight items each, yielded a score between 32 and 128 points. Higher points indicated higher levels of teachers' reformed beliefs. The definition of the construct, reformed beliefs about science education, was critical to this study. According to Sampson et al. (2013):

> The BARSTL is designed to assess the construct, *reformed beliefs about science education*. This construct refers to the remembered experiences, feelings, subjective evaluations, presumptions, and intuitive theories about teaching and learning that teachers hold in regard to the teaching and learning of science. (p. 6)

Validity and reliability. The authors of the BARSTL (Sampson et al., 2013) established reliability, content validity, and construct validity in the development of the instrument. Sampson and associates (2013) developed the BARSTL in several stages, modified based on expert feedback. The authors supervised the evaluation of both construct validity and content validity. The authors used a panel of science educators (both professors and doctoral students) to conduct both evaluations. Content validity informs us how well the items in an instrument measure what the instrument is intended to measure. The items on the BARSTL were drawn from significant reforms documents including, *Science for All Americans* (American Association for the Advancement of Science, 1990), *Benchmarks for Science Literacy* (American Association for the

Advancement of Science, 1993), and the *National Science Education Standards* (National Research Council, 1996). The content validity should not be affected by the status of the population sampled. The documents from which the items were extracted applied to teachers of all grade levels making the content equally relevant to elementary pre-service and secondary in-service teachers, and leading me to consider the content validity suitable for my purpose. After the pilot phase, authors used the instrument with 148 pre-service elementary teachers enrolled in science methods courses, one of the target populations for the BARSTL The authors evaluated the instrument for construct validity, which was defined as, "the extent to which a particular test can be shown to measure a hypothetical construct" (Sampson et al., 2013, p. 7). They calculated correlations between the overall score with each of the four subscales, with strong correlations considered to be supportive of the hypothesis that the subscales measure the construct of reformed beliefs about science education. The R^2 for the four subscales ranged from 0.64 to 0.47, indicating good construct validity. I analyzed my data similarly, examining the correlation between the four subscales and the overall score. Though my sample participants were secondary in-service teachers, as opposed to elementary pre-service teachers, and my n was small (39 compared to an n of 146), my data were quite similar. A bivariate fit of total by subscale yielded four R^2 values from 0.77 to 0.50, all with a $p<.0001$. High R^2 values provided support for construct validity in the development of this instrument with the intended population. My similar values for construct validity supported my decision to extend the use of this instrument to secondary in-service teachers. Sampson and associates also used exploratory factor analysis to establish the construct validity. Items loaded on four factors that reflected the four subscales. For details see Table 7.

Table 7

Comparison of R^2 Values in Two Studies with Different Populations

BARSTL Subscale	R^2 Fit Between Total Score and Subscale	
	Elementary Pre-Service Teachers (Sampson et al., 2013)	Secondary In-Service Teachers (This study)
How people learn	.64	.58
Lesson design and implementation	.64	.77
Teachers and the learning environment	.63	.64
The science curriculum	.47	.50

Note. Adapted from "Development and Initial Validation of the Beliefs About Reformed Science Teaching and Learning (BARSTL) Questionnaire" by V. Sampson, P. Enderle, and J. Grooms, 2013, *School Science and Mathematics, 113*(1), p. 9.

Sampson and associates (2013) established content reliability for the BARSTL using two measures of internal consistency. The first measure, calculation of a split-half coefficient (Spearman-Brown correlation) resulted in a value of 0.80. A second measure, Cronbach's alpha resulted in a value of 0.77. Sampson and associates reported both values indicated a "satisfactory internal consistency" (p. 8). Analysis of my small sample resulted in a coefficient alpha of .83. While Sampson et al. (2013) evaluated the BARSTL as a valid and reliable instrument for pre-service elementary teachers, the author did suggest that a future need was to validate its use with diverse populations of teachers. Though my sample was quite small (n = 39), my results suggest additional study with in-service secondary teachers could further establish this instrument as valid and reliable for a larger group of teachers than originally intended. I concluded that this instrument was suitable for use with my participants.

The TEBS-Self

Administration procedures. I administered the TEBS-Self (Dellinger et al., 2008) in a pre-post design to measure teachers' self-efficacy before and after the reform-based APSI. I used matched pairs *t*-tests to compare the pre- and post-institute differences in scores on these surveys measuring self-efficacy beliefs.

The participants completed a modified TEBS-Self (Dellinger et al., 2008) in paper format within the first hour of the institute. I administered the post TEBS-Self in the afternoon of the last day of the institute. I administered the two post surveys immediately after the afternoon break to avoid two problems. My experience has been that participants are eager to finish activities to begin break, which may cause them to rush. At the very end of the institute, participants may also rush to be finished for the day. While positioning the surveys after the afternoon break had the drawback of failing to capture the final section of the institute program, I believe that this drawback was balanced by the likelihood of more thoughtful responses. This timing was also used for the BARSTL (Sampson et al., 2013).

Organization of the instrument. The authors of this instrument defined the construct of teacher self-efficacy as, "a teacher's individual beliefs in their capability to perform specific teaching tasks at a specified level of quality in a specific situation" (Dellinger et al., p. 752). Items were developed based on a student-centered classroom observation instrument, the *Professional Assessment and Comprehensive Evaluation System* or PACES (Davis, Pool, & Mits-Cash, 2000), which uses items "linked to research in effective teaching and learning" (Dellinger et al., 2008, p. 756).

> The TEBS-Self was designed to assess teachers' self-efficacy beliefs about tasks that are associated with correlates of effective teaching and learning, all within the context of their own classrooms. (Dellinger et al., 2008, p. 756)

The authors used an expert panel to rate 51 items in the development of this instrument. Of those, they selected the 30 highest rated items for use in the final instrument, which utilized a four point rating scale. I choose this instrument because of the separation of definitions for self-efficacy and teacher efficacy. Self-efficacy was important in my theoretical framework, specifically as it relates to the theory of planned behavior (Ajzen, 2005). In contrast to self-efficacy, teacher efficacy was explained this way by Dellinger et al.(2008):

> [Teacher efficacy] confounds (or overlooks) the unique, and possible crucial, role played by teachers' beliefs in their ability to perform the wide variety of teaching tasks (particularly those tasks that work!) required in various teaching and learning contexts. (p. 753).

Validity and reliability. Conserving time was a major consideration when I originally planned the survey portion of the study. This concern led me to modify the TEBS-Self (Dellinger et al., 2008) by reducing the number of items. This adjustment from 30 to 24 items required an analysis of the modified instrument to verify that the shortened test was still reliable.

I used the program STATA (StataCorp LP, 2017) to run an exploratory factor analysis of the pre-institute TEBS-Self survey results to reduce and cluster the data into categories (Gaskin, 2014). My goals were to establish internal consistency for the entire shortened survey, establish internal consistency for individual categories, and compare these categories with those of researchers involved in instrument development. After loading the data from an Excel file, I ran a factor analysis in STATA followed by a scree plot of the eigenvalues. The eigenvalues above one were retained, leading to a four-factor solution accounting for 78.57% of the variance. These results were subjected to a varimax rotation to maximally separate the factors (Gaskin, 2014). Factors that loaded above .45 were retained and sorted numerically by factor. These data are represented in Table 8.

Table 8

Factor Loadings for Exploratory Factor Analysis With Varimax Rotation of Modified TEBS-Self

Item on modified TEBS-Self		Positive Classroom Environment	Accommodates Individual Differences	Communication/ Clarification	Higher-Order Thinking Skills (HOTS)
23.	Learning Environment Supports Cooperative Work	**0.8685**	0.0915	0.1623	0.2084
24.	Maintains Positive Climate	**0.8359**	0.1526	0.0461	0.2081
04.	Manages Routines for Learning	**0.6258**	0.2226	0.3395	0.1453
07.	Communicates Learning Task Importance	**0.6063**	0.3422	0.4444	-0.2014
05.	Maintains Student Engagement	**0.5334**	0.4218	0.1996	0.3487
16.	Monitors Student Involvement	**0.4968**	0.2256	0.3218	0.1820
20.	Learning Environment Accommodates Special Needs	0.2229	**0.8905**	0.0819	0.0622
21.	Improvement Includes Those With Learning Disabilities	0.1866	**0.8729**	0.1880	0.1637
8.	Tool Choice Accommodates Individual Differences	0.0252	**0.6854**	0.3072	0.3654
01.	Plans for Individual Differences	0.1700	**0.5057**	0.2159	0.4887
03.	Maximizes Learning	0.0401	**0.4580**	0.2293	0.3690
13.	Provides Suggestions for Improving Learning	0.1460	0.2241	**0.7975**	0.2272
12.	Gives Feedback for Learning	0.1709	0.1433	**0.7947**	0.2072
06.	Communicates Learning Outcomes	0.4060	0.2531	**0.5620**	-0.1980
14.	Actively Involve Students	0.1359	0.1521	**0.4684**	0.4300
11.	Clarifies Misunderstandings	0.2274	0.3493	**0.4602**	0.1414
22.	Provides Positive Influence on Academic Development	0.3036	0.2464	**0.4512**	0.3569
09.	Provides Levels of Learning	0.2536	0.2466	0.1388	**0.7069**
15.	Solicits Higher Order Thinking Questions (HOT)	0.3178	0.3175	0.2019	**0.6094**
18.	Involves Students in Developing HOT Skills	0.3481	0.2610	0.3772	**0.5017**
	Percent of Variance	0.2259	0.2090	0.1877	0.1631
	Cumulative Variance		0.4349	0.6226	0.7857
	Reliability	**α=0.8691**	**α=0.8691**	**α=0.8312**	**α=0.8066**

Note. Factor loadings >.45 are in boldface. 4 items without >.45 loading have been omitted. *TEBS-Self* is Teachers' Efficacy Beliefs System-Self Form. Adapted from "Measuring Teachers' Self-efficacy Beliefs: Development and use of the TEBS-Self," by Dellinger, A. B., Bobbett, J. J., Olivier, D. F., & Ellett, C. D, 2008, *Teaching and Teacher Education, 24*, p. 764.

To establish the reliability of these data I determined a coefficient alpha (scale reliability coefficient in STATA) of 0.9431 for the entire data set collected using the shortened test. In additional to a finding of internal consistency for the entire data set, each of my four factors had an individual coefficient alpha that was acceptable, with the lowest being 0.8066. The KMO or Kaiser-Meyer-Olkin Measure of Sampling Adequacy test was 0.767, a value large enough to allow the meaningful use of factor analysis for grouping (Gaskin, 2014). Additionally, Barlett's Test of Sphericity returned a Chi-square of 639.620 with 276 degrees of freedom and a p-value of 0.000. This finding of significance is necessary if I am to look for associations between the variables. A non-significant result would indicate a lack of association (Gaskin, 2014).

I found a reasonable alignment between my factor categories and those of the previous researchers as shown in Table 9. The results from the three studies used in the development of the TEBS-Self were themselves not perfectly aligned, and authors of the instrument themselves had suggested additional work on this model (Dellinger et al., 2008). My factor category, Positive Classroom Environment (PCE) did not have a perfect match with clustering from other researchers. Instead, this category incorporated thoughts in Management/Climate (MC), Motivation of Students (MS), Classroom Management (CM) and Maintaining Positive Classroom Climate (PCC). Using these combinations, five of my six items grouped similarly to the categories established by others.

Items in my category, Accommodating Individual Differences (AID), aligned to similar categorization from at least one of the previous researchers for four of the five items. My item three (also number three in the original), summarized as "maximize learning" was not included in the cluster of AID for any of the other researcher and it had the lowest loading factor among my AID items. Among my group of secondary teachers, maximizing learning may have meant maximizing learning of the individual by accommodating for differences. In contrast, in the studies with teachers of younger students, who were the pilot participants, item three clustered with classroom management. For the teachers of younger students this item may have been interpreted as managing the classroom to maximize learning as a whole.

In the category Communication/Clarification (CC), my item categorization was similar to the clustering of others for four of six items. Clustering placed my item 14 (original 19) in the group Communication/Clarification (CC), but two of the three comparison studies included it in Higher Order Thinking Skills (HOTS). The item is "actively involved students in developing concepts." While the HOTS placement is easy to justify, I pondered the alternate placement found in my results. It may reflect a traditional viewpoint of a secondary level teacher of communicating *to* and clarifying *to* students while developing concepts as active involvement. While not the reformed view of *active*, it offers a possible explanation for the cluster seen in my study.

The factor HOTS was aligned with the reference studies for two of the three items that clustered here. Item nine (original 14) was "provides students with opportunities to learn at more than one cognitive and/or performance level." Only one other study included this item in any factor, and that factor was AID. There seemed to be a difference in interpretation between elementary and secondary teachers as to whether learning at different levels is accommodating instruction for where students are (AID), or advancing to another, presumably higher-level (HOTS).

Table 9

Comparison of TEBS-Self Item Assignment Between Studies

Item Number (Original)	Killough	Olivier (2000)	Bobbett (2001)	Dellinger (2001)
4 (4)	PCE	MC	CM	MLR
5 (6)	PCE	MC		
7 (11)	PCE		CC	
16 (22)	PCE	CC		MFL
23 (30)	PCE	MS	CM	
24 (31)	PCE			PCC
1 (1)	AID	AID	PAID	AID
3 (3)	AID	MC		MLR
8 (13)	AID	AID	PAID	AID
20 (27)	AID		PAID	AID
21 (28)	AID	HOTS	PAID	
6 (10)	CC		CC	
11 (16)	CC	CC	CC	CC
12 (17)	CC	CC	CC	MFL
13 (18)	CC	CC		MFL
14 (19)	CC	HOTS	HOTS	
22 (29)	CC	MS		
9 (14)	HOTS	AID		
15 (20)	HOTS	HOTS	HOTS	
18 (25)	HOTS	HOTS	HOTS	

Note. PCE (Positive Classroom Environment), AID (Accommodates/Accommodating Individual Differences), HOTS (Higher Order Thinking Skills), CC(Communication/Clarification), MC(Management/Climate), MS (Motivation Of Students), CM (Classroom Management), PAID (Planning And Accommodating Individual Differences), PCC(Maintaining Positive Classroom Climate), MFL (Monitoring For Feedback And Learning), MLR (Managing Learning Environment). Adapted from "Measuring Teachers' Self-efficacy Beliefs: Development and use of the TEBS-Self," by Dellinger, A. B., Bobbett, J. J., Olivier, D. F., & Ellett, C. D, 2008, *Teaching and Teacher Education, 24*, p. 759.

Dellinger et al. (2008) reported that 45 professional educators judged the TEBS-Self as a valid instrument in their independent dissertations. Reliability of the original instrument was established with a population of elementary teachers. While most items in my modified instrument clustered in a similar way to that found in the initial study, a few items did not cluster as well. As my sample size was very small in this particular study, I strongly recommend that the findings I reported here with the modified version be used to inform future work to more extensively establish reliability with a population of secondary teachers in their use of the instrument holding all of the original items. Nonetheless, I was satisfied with the overall reliability on the sub-set of items I used in this study and deemed the modified version acceptable for use.

Phase II: Daily Reflections.

Participants answered four reflection questions each of the first three days of the institute as part of Phase II. This reflections time occurred after the afternoon break to prevent participants from rushing through the writing. I selected the prompts for reflection based on activities and discussions of the day, from a prepared list (see Appendix C). These reflections served two purposes. First, they were formative. As such, I reviewed the days' reflections each evening after they were written to guide changes in the agenda to meet the expressed needs of the participants. Second, I also used daily reflections as a data source for analysis for several research questions (see Table 4).

Phase III: Interviews

The Phase III instrument held a set of semi-structured interview questions. I used a questioning route based on an approach used by Krueger and Casey (2015) that began with opening questions, followed by transition and key questions, and ending with an open-ended question allowing participants to add information they felt was relevant (see Appendix D). I used the results from the BARSTL (Sampson et al., 2013) and TEBS-Self (Dellinger et al., 2008) to select ten participants for this phase. I calculated the difference between pre-institute and post-institute TEBS-Self and BARSTL scores for each participant, rank ordered these scores, and used them to purposefully select the Phase III participants. The interview participants were teachers with large differences on either the BARSTL or the TEBS-Self. Interviews took place either face-to-face or on the telephone during the school year following the summer institute, from October to March. I recorded these interviews and transcribed them for analysis.

Qualitative Validity Approaches

Establishing validity was important for both qualitative and quantitative aspects of the study. In mixed methods protocols, validity is determined for the individual qualitative and quantitative procedures according to the traditions of each. I established the validity of the qualitative analysis by conducting member checks with a selection of participants (Lincoln & Guba, 1985). Participants, who responded to a request to review my analysis of their words, agreed that I captured their thoughts at the time they either wrote them down during reflections, or spoke them during an interview. In addition, I used triangulation, to establish the validity of the analysis by looking at the events from more than one data source. Creswell and Miller (2000) defined triangulations as, “a validity procedure where researchers search for convergence among multiple and different sources of information to form themes or categories in a study” (p. 126). Using an across methods approach, I found that the interview, reflection, and goal data strongly converged.

Data Analysis

I used both quantitative and qualitative analytic methods in the mixed methods design for this case study, adopting the traditions of each approach. I used the research question to select both type of data source and analytic method. A case study involves making a decision about the boundaries of a study rather than decisions about methodology, and case study is definitely a suitable approach for mixed methods (Flyvbjerg, 2011). I considered the data from two different institutes as a single bounded case, and they were analyzed together. In this embedded mixed methods design, I used the qualitative analytic phase to understand results from the quantitative analysis and to provide insights that could only come from blending the two approaches.

Quantitative Analysis

I used traditional statistical methods to examine the quantitative data provided through the surveys (Ott & Longnecker, 2010). This included the use of statistical software. I used both JMP (SAS Institute, 2015) and STATA (StataCorp LP, 2017). A 0.05 alpha level was used to determine significance as appropriate. Statistics met the appropriate assumptions for the given tests.

The TEBS-Self (Dellinger et al., 2008) and BARSTL (Sampson et al., 2013) data were explored using descriptive statistics including standard deviation, standard error, interquartile range (IQR), minimum, maximum, and confidence intervals. Normality was assessed on the raw scores and the differences between pre and post scores. A matched pairs *t*-test was used to compare the pre-institute and post-institute means for both instruments. The sample size was adequate for these statistics, n=38 for the BARSTL, and n=40 for the TEBS-Self.

Qualitative Analyses

Directed content approach. I used a directed content analysis approach (Hsieh & Shannon, 2005) to code the qualitative data (pre-institute, reflections, and interview). Using this method, data was coded using predetermined codes derived from theory. I used the two theories that underlie my theoretical framework as a source for the codes. This resulted in a three level coding schema that is fully explained in Chapter Four. This approach let me connect participants' words and actions with my selected predictive theories. I also quantified some interview data to provide a relative weight to the distribution of comments from reformed to traditional perspectives.

Conventional content analysis. I used a conventional content analysis approach (Hsieh & Shannon, 2005) to make sense of participants' pre-institute needs, and to analyze data related to the activity systems associated with teaching AP Biology. Using this model, I coded, categorized, and developed themes based on the qualitative data. This approach is useful when there is no existing theory (Hsieh & Shannon, 2005).

Murphy and Rodríguez-Manzanares (2014) analyzed nine Cultural and Historical Activity Theory (CHAT) studies to find that the researchers used a common analysis model. The qualitative analysis in activity theory usually follows a naturalistic method of interpretation with reporting in a text-based format (Murphy & Rodríguez-Manzanares, 2014). Murphy and Rodríguez-Manzanares (2014) found the resulting themes were applied to the seven components of the activity system: Subject, Object, Tools, Norms, Community, Division of Labor, and Outcome. After the researchers associated themes with the seven components, they then proceeded to identify and analyze contradictions within the system. I used this model with the qualitative data sources to code, categorize, and place the data into themes.

Mixed Methods Analyses

I used a mixed methods approach to connect the qualitative data with the quantitative data. Jacobson and Kapur (2012) supported integrating quantitative and qualitative approaches to avoid oversimplification that results from a quantitative only approach. This integration allowed me to show changes in beliefs over time through comments from individual participants that were directly associated that same individual's pre-post survey beliefs change.

Limitations and Delimitations

Limitations

It is beyond the scope of this study to examine professional development in other subject domains, in instances with shorter duration, and, indeed, even in other APSIs in

AP Biology. While these limitations do exist, I do believe that this work can support the AP Program by identifying changes in professional development of APSIs that positively affect teachers. Due to the selection of participants within the two institutes for which I served as consultant, however, generalization beyond the test population is not possible.

For this study, the sample size was reasonable and adequate to meet assumptions of the statistical tests, but a larger sample size would have provided more convincing evidence. Additional institutes could also provide a clearer picture of the effects of these institutes on teacher reformed beliefs and self-efficacy. In retrospect, I identified a limitation in this study regarding my selection of the instruments measuring reformed beliefs and self-efficacy. Authors of both the BARSTL and the TEBS-Self piloted their instruments using pre-service elementary school teachers. My use of these instruments with high school AP teachers was outside of the range in which the instruments had been used previously. However, the authors of both studies pointed to the need to validate these instruments with different groups including different populations of teachers.

In order to save time at the institute, I modified the TEBS-self by cutting six items from the original document. While modification of this instrument was supported by the authors, I felt it was essential to perform a factor analysis after its use to confirm that the instrument's internal validity held up with the item reduction.

Delimitations

This sample was a tiny subset of teachers who regularly attend science professional development events. I selected biology teachers at an APSI because of my own personal experience and access to this group of teachers. While APSIs in biology exist for new and experienced teachers, I selected only new teachers for this study. As the current reform-based AP Biology program had been in use for several years now, I expected experienced teachers to be more familiar with the science teaching reforms. By choosing to work with a group of new AP Biology teachers, I expected that there would be a greater opportunity for growth in both reform science teaching beliefs and self-efficacy as a result of a reform-based APSI.

I considered several qualitative methods for this study. Grounded theory was ruled out, as it was not compatible with my choice of activity theory to guide my analyses. While the authors of activity theory call it a framework for understanding human activity including learning, the theory itself relies on underlying socio-cultural theoretical perspectives. Grounded theory is the opposite approach, building theory from the ground up without preconceived ideas (Birks & Mills, 2015). When choosing between an ethnographic approach and a case study approach, I chose a case study approach because the APSI actually fits the description of a "bounded case" of two APSIs conducted in one summer and my intent is to understand a specific issue (Creswell, 2013). In an earlier book, Creswell (2008) placed a case-study approach under the umbrella of ethnographic methods. A case study approach is compatible with activity theory, also called cultural and historical activity theory, or "CHAT," because it is a socio-cultural analysis within a bounded system using multiple forms of data. A primary objective of the case study is to assist understanding of a situation (Lincoln & Guba, 1985), which is also the goal of activity system analysis.

Role of the Researcher

I conducted this quality improvement project within my role as a College Board Consultant (consultants are not College Board employees), providing training during APSIs. I was the facilitator for the APSI sessions that provided the context for this study. The questions of how to shift teachers' beliefs to a more reformed viewpoint during AP professional development occurred to me as a result of my role as a consultant. Furthermore, I was fortunate to have assistance in conducting this study from other individuals associated with the APSIs with whom I have both personal and professional relationships. My preparation to do this study was enhanced through my graduate coursework, including statistics course work that supports my quantitative analyses and qualitative and mixed methods courses to support my analyses of verbal data, including the post-workshop interviews. In addition to serving as an AP Biology facilitator since 2000, I also have 22 years of experience teaching AP Biology. Both experiences have yielded valuable prior information about biology teachers' concerns and frustrations as they made their transitions to become AP teachers.

Ethical Considerations

I have reviewed AERA's Code of Ethics and received IRB approval to conduct this mixed methods study before any data were collected. To assure consent, I informed the institute personnel responsible for hiring me as an institute facilitator that I desired to collect data at the workshop that this information would be used in my dissertation. The directors of the institutes granted permission for this study. Potential participants had a choice about participation in this study, and I provided them with an informed consent form prior to collecting their information. They were informed that they were free to decline or quit their involvement during the institute without any negative consequence. I have kept all personally identifiable information confidential that was collected from participants. I assigned codes to participants' names to work with the data to avoid any unintentional biases in analyses. Additionally, I am not disclosing the identity of the APSIs where information for this study was collected.

Summary

Complexity of context dictated a set of five research questions, each with its own data sources and methods for collection, analysis, and interpretation. The first two research questions set the stage for participants engaged within the activity system of the APSI: What were participants' goals in attending the APSI, and did my revised APSI curriculum enable these goals to be met? More specifically in line with my own goals in the revision of the curriculum, were my goals met for the revision? Were my revisions involving the use of an extensive student-centered, active learning approach with participants successful in increasing participants' beliefs about reformed teaching and self-efficacy? To get a sense of participants' goals, I chose a simple, open-ended question requesting information about participants' goals administered by email before participants arrived at the APSI and a content analysis to get an underlying sense of their entry-level goals. To satisfy my own need for information about the success of my revised APSI curriculum, I chose to statistically compare pre- and post-workshop quantitative surveys to get a sense regarding participants' beliefs. To explore the relationship between these beliefs changes and institute activities I tied survey results to threads of statements from individual participants over time. The fourth research question related to participants' perceptions after the institute. What beliefs, intentions and behaviors associated with the institute made it to the classrooms of participating teachers? Finally, for Question Five, I looked at the activity systems associated with teaching AP Biology, to find the tensions that affect the transfer of reformed beliefs to the classroom.

Chapter Four of this dissertation provides the details of the findings in regard to answers for each of the five research questions, clustered into three basic sections. Section I provides the results of analyses of instruments associated with Questions One and Two and the application of Question Two analyses to Question Three. Section II provides the results of my analysis in regard to Question Four. Finally, Section III provides the results of my analysis in regard to Question Five.

CHAPTER IV

RESULTS

Attending an APSI for AP® teachers is an important preparatory event for science teachers tasked with the teaching of AP Biology® for the first time. AP Biology is taken in high school, most commonly by junior and senior level students. Considered the equivalent of an introductory biology course for majors at the university level, the course includes a final examination to document successful completion of the course. Students are tested in May, and those with a qualifying score may earn college credit, depending on the policy at their chosen institution. The stakes are high for the students, but also for the AP teachers and their schools. Popular magazines now tie school rankings to the number of students taking tests as compared to the total school population (Mathews, 2000).

In 2013, the College Board administered the first exams for a completely redesigned AP Biology course (The College Board, 2013). The redesign shifted the traditional course to a student-centered one, a move consistent with national science reform initiatives. Documents on reform point the way forward to a society of science literate citizens more capable of asking and answering questions about the world around them--questions and answers essential to our prosperity not only as a nation, but also as global citizens inhabiting a shared home.

As an experienced APSI instructor, I understood all too well how important an AP Biology course could be to students' growth in science literacy, as well as to their futures in college. In that regard, I decided to examine the association between new AP teachers' attendance at an APSI and changes in their beliefs about reforms in science teaching, as well as changes in their self-efficacy in teaching science. I used both quantitative measures and participant reflections and interviews to evaluate the overall success of my APSI offerings in effecting change in teachers' abilities to offer a reformed AP Biology course to their students. In this chapter, I provided an outline of overall study findings sequentially addressed by five research questions. I divided this lengthy chapter into three sections, Section I: Survey Data with Qualitative Evidence, which provides the results of my content analysis of participants' responses on a pre-APSI survey and on two pre- and post-APSI administrations of instruments measuring self-efficacy and beliefs about reform and qualitative support; Section II: Theoretical Alignment, which connects interview data to the theory of planned behavior and self-efficacy theory in a directed content analysis approach; and Section III: Interference with Classroom Transfer, in which I examine issues that have the potential to reduce the impact of professional development concerned with science reforms. I decided to cluster results of these three sections because I saw natural divisions between the more concrete survey data and support (Section I), the connections with theories that help explain the data (Section II), and the analysis of hurdles teachers face as they return to the classroom with new skills and ideas in the area of science reforms (Section III).

Section I: Beliefs Changes Associated with the Workshop

Research Question One: Goals and Needs

What are participants' particular goals and needs going into the APSI? A week before the beginning of the APSIs, I communicated with participants via e-mail to provide information about the workshop, to request their consent for their participation in a research study, and to provide a link to a pre-workshop survey. Relevant to this research question was the following prompt on the survey, "Please tell me about your goals for our APSI. Are there any particular topics you want to see covered in the workshop?" Thirteen of the 40 responding participants did not answer this question, providing a response return of 68% of the participants. I asked this question to find out more about participants' goals and to be sure that the learning activities I had planned would meet their needs. I used conventional content analysis as described by Hsieh and Shannon (2005) to consolidate the information. First, I read the responses multiple times to get an overall impression of the data set before I segmented the data into individual phrases or "comment segments." My segmentation of the responses yielded 62 segments, which I then coded. After coding, I grouped coded segments into categories. Overall, I found that participants had well defined goals for the workshop. This was not a surprising finding as most participants had just two months to prepare for the rigorous AP course to which they had committed. Frequencies of the comment segments regarding participants' expressed goals appear in Table 10. While all of the comment segments referred to preparation for teaching the course, I was able to separate them into three distinct categories. Even though I did not define the categories before coding, I cannot discount my unconscious bias toward the theoretical framework. I found that all of the coded segments clustered into one of the three objectives upon which I had focused the institute. These three categories were: (1) Preparation for Teaching AP Biology, (2) Goals Related to Science Reform, and (3) Goals Related to Self-efficacy. The content analysis yielded a three-part answer to the first research question regarding participants' particular goals and needs going into the APSI. In terms of Category One (preparation to teach AP Biology), participants wanted to know about testing, curriculum, pacing, and required lab components. Additionally, eleven segments indicated concerns about issues specific to particular school situations, such as limited class time or a tight budget. Category Two (goals relating to science reforms) held about 25% of the comment segments. Within this category, participants expressed a desire to learn more about student-centered approaches and successful facilitation of inquiry labs. Category Three (self-efficacy) held the remaining content segments indicating their desires to increase their confidence in teaching the AP Biology course.

Table 10

Pre-institute Participant Goals

Goals	Comment segments		
	N	%	Characteristic responses
Preparation for teaching AP Biology			
School specific concerns	11	17.7	Labs on a strict budget
Content concerns	11	17.7	I want to learn the curriculum
General lab concerns	8	12.9	I'm very interested in learning how to conduct the labs most effectively
General preparedness	7	11.3	How to prepare students for the AP test
Pacing	4	6.5	My goals are to learn the pacing of AP Biology
Goals related to science reform			
General	10	16.1	To make a better classroom for student-centered learning
Inquiry labs	6	9.7	How to be inquiry driven at this high level
Goals related to self-efficacy	5	8.1	I also want to be a better biology teacher
Total	62	100.0	

Research Question Two: Beliefs Changes

How do participants' beliefs change in association with attendance at an APSI workshop? Participants completed two surveys, the BARSTL (Sampson et al., 2013) and the TEBS-Self (Dellinger et al., 2008), before and after participation in the four-day APSI. The BARSTL measured participants' beliefs about reformed science teaching and learning, and the TEBS-Self measured participants' beliefs about their own teaching efficacy. I compared the pre- and post-institute survey scores for both instruments, using matched pairs *t*-tests, to determine if participants' attendance at the APSI was associated with changes in these scores.

The BARSTL results. I analyzed thirty-eight pairs of BARSTL surveys from the group of 40 participants. One participant did not complete the pre-institute BARSTL due to a data submission problem with the Goggle form, and a second participant did not complete the back page of the post-institute survey. I did not use the survey data from these two participants in my analysis. I found several surveys where participants enclosed two adjacent answers within the circle they drew to indicate their choice. In these cases I used the mean of the two marks. I used the program JMP (SAS Institute, 2015), to conduct matched pairs *t*-tests to compare the pre- and post-institute means for the overall BARSTL, as well as for each of the four subscales comprising the instrument. The analysis met four assumptions of the *t*-test (Laerd Statistics, n.d.), as follows: (1) the dependent variable, BARSTL score, was continuous, (2) the independent variables (pre- and post-test score for an individual) were related, (3) there were no outliers in the score differences, and (4) the score differences were approximately normally distributed. I used a normal quantile plot to assess normality. I found no violations of the statistical assumptions for the overall BARSTL or any of the four subscales.

Setting a significance level of 0.05, I found that the data showed a statistically significant difference for the overall BARSTL score, as well as for three of the four subscales. The overall BARSTL mean difference showed a *t*-ratio of 5.40519 and a 2-tailed p value of <0.0001. The highly significant difference between means before and after the APSI indicated that APSI participants held more reformed beliefs at the end of the four-day workshop than they did at the beginning. Similar results were seen in three of the four subscales. I found significant increases for the subscales, How People Learn About Science (HPL), with a *t*-ratio of 4.194352 and $p = 0.0002$, Lesson Design and Implementation (LDI), *t*-ratio 4.483699 and $p < 0.0001$, and Characteristics of Teachers and the Learning Environment (CLE), *t*-ratio 4.511601 and $p <0.0001$. I detected no significant difference for the subscale Nature of Science (NOS). Additional statistical details may be found in Table 11.

The data revealed a relationship I did not expect, which resulted in my development of an additional research question. I performed a post hoc independent *t*-test to assess the relationship between the overall BARSTL score and teaching experience. To perform the test, I divided the participants into two groups based upon their years of teaching experience: "more experienced" (five or more years) and "less experienced" (four or less years). The division resulted in two equal groups of 19 participants. The assumptions of the statistical test were met and I analyzed the data using JMP (SAS Institute, 2015). This test returned significant results with a *t*-ratio of 3.762662. and a $p > |t|$ of 0.0006*. The Brown-Forsythe test showed equal variance. Together these results indicated a positive relationship between more experience in teaching with much greater changes in their reformed belief scores. The mean difference in BARSTL scores for more experienced teachers was 7.97368, as compared

Table 11

Statistical Summary of Participants' Matched Pairs t-Test for the BARSTL

	BARSTL	HPL	LD &I	CLE	NOS
Posttest	94.8158	22.9605	24.1316	25.0132	22.7105
Pretest	89.8421	21.7105	22.2368	23.5789	22.3158
Mean difference	4.97368	1.25	1.89474	1.43421	0.39474
N	38	38	38	38	38
DF	37	37	37	37	37
t-Ratio	5.40519	4.194352	4.483699	4.511601	1.226736
Prob> |t|	<0.0001*	0.0002*	<0.0001*	<0.0001*	0.2277
			Summary Statistics on the Difference		
Std Dev	5.67230	1.83712	2.60498	1.95963	1.98357
Std Error	0.92017	0.29802	0.42258	0.31789	0.32178
IQR	12	3	4.125	3	3
Minimum	-3	-3	-3	-2.5	-3
Maximum	15	4	9	5	5
Upper 95%	6.83812	1.85385	2.75097	2.07832	1.04672
Lower 95%	3.10925	0.64615	1.0385	0.7901	-0.2572

Note. The symbol "*" indicates p<0.05. Abbreviations include the title of the instrument and its subsections: BARSTL = Beliefs About Reformed Science Teaching and Learning instrument, HPL = How People Learn, LD &I =Lesson Design and Implementation, CLE=Characteristics of Teachers and the Learning Environment, NOS = Nature of Science. From V. Sampson, P. Enderle, & J. Grooms, (2013), Development and initial validation of the beliefs about reformed science teaching and learning (BARSTL) questionnaire. *School Science and Mathematics, 113*(1), 3-15.

to 2.00000 for less experienced teachers. These findings suggest that more recent pre-service teacher training may include more reformed ideas in their coursework than the pre-service training received by more experienced teachers. These results are displayed as a box and whisker plot in Figure 9.

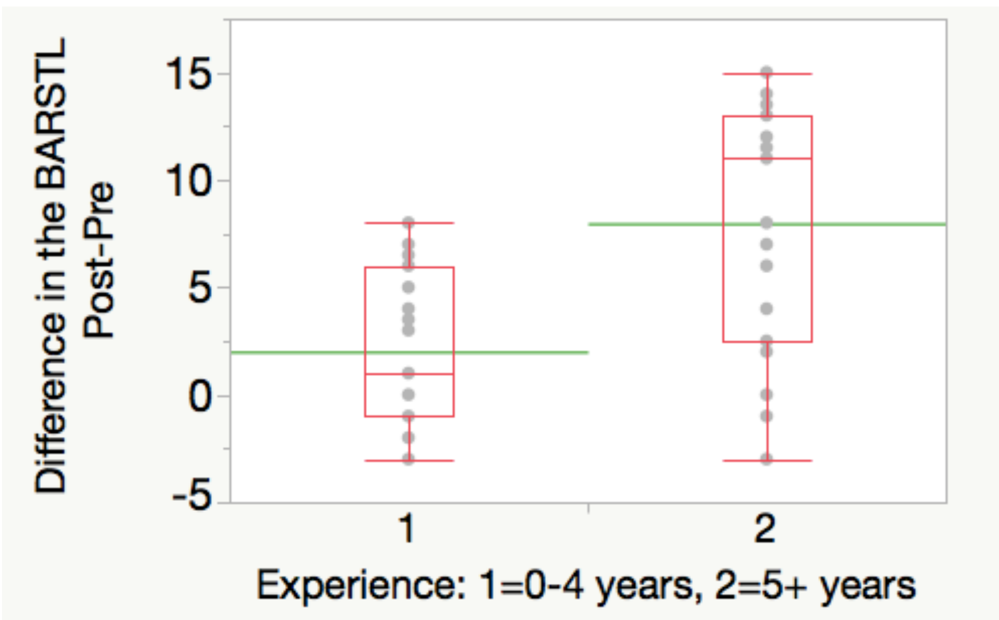

Figure 9. BARSTL score difference by years of experience in two groups of APSI participants (n=19 in both groups). The line added to the box and whiskers plots shows the mean BARSTL difference for each group.

These findings led me to craft another post hoc question. Were the starting and ending BARSTL scores different among the two experience groups? I used a Wilcoxon rank sum test to compare the pre- and post-institute BARSTL scores. I selected this non-parametric test due to the presence of outliers, which is a violation of parametric assumptions. I found a significant difference in pre-institute scores between the two experience groups (Chi square = 7.4067, DF 1, $p > 0.0065$). Less experienced teachers began the institute with higher scores on the BARSTL, (mean = 92.7), compared to the mean for more experienced teachers (mean = 86.95). The post-institute BARSTL scores of the two groups were nearly indistinguishable (means = 94.89 and 94.7), with no significant differences indicated by the Wilcoxon rank sum test (Chi-square = 0.0173. df 1, $p > 0.8952$).

In summary, I found that post APSI scores indicated among all participants an increase in overall beliefs about reformed teaching, with increase in three of four subscales. While increases were found for both groups of participants, the increase in scores was much larger among more experienced teachers. In contrast, post-institute beliefs about reformed teaching were nearly indistinguishable between participants grouped by teaching experience. Regardless of starting point, participants completed the workshop with nearly equivalent reformed beliefs. If future investigations support this preliminary finding reported here, offering this workshop using reform strategies such as active learning, inquiry, collaboration and reflection, may be effective in closing the gap in knowledge of reformed beliefs between more and less experienced teachers.

The TEBS-Self results. Forty participants responded to the modified TEBS-Self, once at the beginning of the APSI and again after the afternoon break on the last day. As with the BARSTL, I analyzed the surveys with a matched pairs *t*-test using a significance level of 0.05. The assumptions of the matched pairs *t*-test were met, the dependent variable was continuous, and the scores were correlated for each participant, there were no outliers and the data for the difference was approximately normally distributed. The possible scores for the 24-item modified instrument ranged from a minimum of 24 to a high of 96 points. Participants marked items about their confidence to teach using a one- to four-scale with a higher number indicating a greater degree of confidence. As with the BARSTL, if a participant enclosed two numbers when circling their choice, I used the mean to calculate their score.

I found a significant difference between the pre- and post-institute mean scores of self-efficacy on the modified TEBS-Self. The *t*-ratio was 3.65268, and the p-value for a two-tailed test was 0.0008 (see Table 12). A large score range existed in both pre- and post-institute surveys. In particular, the range of the scores on pre-institute survey (48) was larger than the post-institute range (38). As the amount of change possible on this instrument was different for scores on opposite ends of the range span, I was not surprised to see that individuals starting the institute with lower self-efficacy scores had higher gains than those starting with higher scores. Participants with very low self-efficacy were likely to have bigger gains in confidence. Participants scoring at the high end of the self-efficacy instrument made smaller gains. In some cases I observed a lower self-efficacy score on this measure after the institute, though this decrease was generally small.

Table 12

Matched Pairs t-Test and Statistical Summary for the Modified TEBS-Self (N=40)

Statistic	Pre-Institute	Post-Institute	Mean Difference
Mean	70.725	75.4875	4.7625
Standard Deviation	11.934624	8.7826223	8.2462015
Standard Error	1.8870298	1.3886545	1.3038389
IQR	17	10.875	13
Minimum	41	56	-8.5
Maximum	89	94	22
Upper 95%	74.541878	78.296319	7.3997632
Lower 95%	66.908122	72.678681	2.1252368
t-Ratio			3.65268
Prob> |t|			0.0008*

Note. Post-Pre. TEBS-Self = Teachers' Efficacy Beliefs System-Self Form. Modified for use at the APSI from original TEBS-Self in "Measuring Teachers' Self-efficacy Beliefs: Development and use of the TEBS-self," by A. B. Dellinger, J. J. Bobbett, D. F. Olivier, & C. C. Ellett, 2008, *Teaching and Teacher Education, 24*, p. 764. Values marked with "*" are significant.

Looking at the surveys together. The TEBS-Self and the BARSTL both showed significant differences when teacher participants took the surveys before and after a four day APSI. In the BARSTL section, I discussed the relationship between teaching experience and BARSTL difference, with more experienced teachers showing more growth. I saw the opposite effect with the results for the TEBS-Self. Less experienced teachers showed more growth in self-efficacy in association with the four day APSI. My interpretation is that teachers with more experience would already be more confident about their teaching and have less room for growth. These results are represented in Figures 10 and 11.

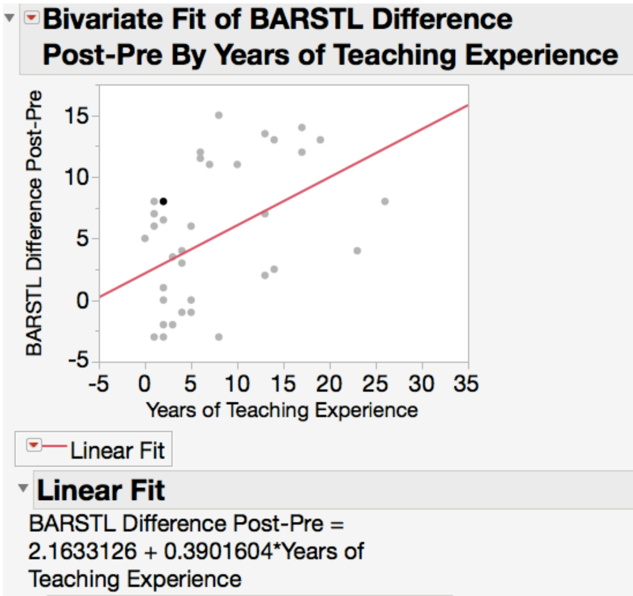

Figure 10. Linear fit for years of experience against change in the BARSTL.

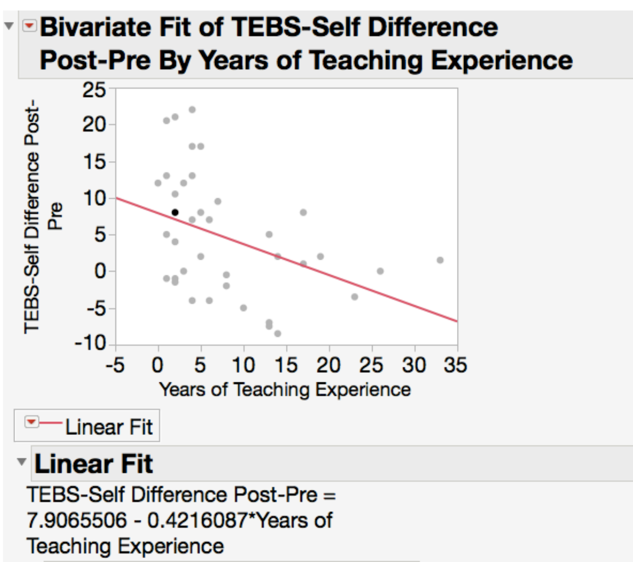

Figure 11. Linear fit for years of experience against change in the TEBS-Self.

Research Question Three: Connecting the APSI to Change

How do I make sense of the changes in self-efficacy and reformed beliefs observed on participants' surveys after they attended the institute? The results from my quantitative comparisons of pre- and post-institute surveys indicated significant, positive difference in participants' self-efficacy and reformed science beliefs. To learn more and make some sense of these differences, I employed a mixed methods approach. I connected quantitative survey results with qualitative input from participants' pre-institute goal statements, reflections during the institute, and post-institute interviews. To analyze participants' qualitative data, I began with the typical techniques for content analysis by breaking the verbal and written data into thought segments and coding these segments. Rather than using traditional open coding to derive codes for the analysis, however, I used directed content analysis (Hsieh & Shannon, 2005). In directed content analysis, codes are derived from theory. In deference to theory, I based primary codes for the directed content analysis on the theories I used to ground the conceptual framework for my study; i.e., Ajzen's (2005) theory of planned behavior and Bandura's (1977) theory of self-efficacy. These details of this coding scheme are found with Question Four.

Tables 13 through 22 indicate progressions of change for nine participants. I designed these tables to provide examples of associations of survey results with participants' verbal and written data. For each table, I compiled sample threads from a participant's statements to show a pattern of change over time (i.e., pre-, during-, or post-institute) for a construct relating to either reformed teaching or self-efficacy. The thread directly relates to theory, connecting some aspect of change in the individual participant's beliefs about reformed teaching, self-efficacy change, intention, or behavior. Each of the resulting tables presents my construction of "threads" of evidence from the individual's comments as they progressed through time, which I then associated with changes in participants' responses on either the BARSTL or TEBS-Self**.** Each table also provided the related scores with each thread for reference.

Participant Two: Self-efficacy and student-centered learning. Table 13 displays the thread of change for Participant Two, a teacher with four years of teaching experience who entered the APSI as a new AP Biology teacher. This thread indicates a progression of change in Participant Two's attitudes about the reformed strategy of active learning. I developed this progression as one following Ajzen's (2005) model of the theory of planned behavior, which links beliefs to behaviors through intentions (see Figure 6). I chose comments to reflect changes from intention to implementation. Participant Two expressed beliefs about student-centered learning, specifically active learning, in statements made during and after the institute. Though expressing some concerns about her preparation, this participant indicated an intention to focus on active learning with students. Realized classroom behavior described by the participant specifically detailed how she had been using active learning strategies in her classroom. This participant also reported an increase in her own beliefs about her abilities (self-efficacy) to orchestrate active learning in her own classroom, which she attributed to the APSI experience. While this participant showed a large 22-point gain on the TEBS-Self score, which resonates with her comments regarding a change in self-efficacy, the

Table 13

Evidence Supporting Changes in Beliefs about Active Learning and Self-Efficacy in Participant Two

Data source	Participant's responses
Day 2	Love the idea, understand the benefits. (Thoughts on active learning)
Day 2	It's my goal to improve my students' active learning dramatically this year.
Interview	But incorporating it (i.e. active learning) into the biology classroom, I really didn't know enough about it to do it. (A reflections looking backward about the participant's APSI entry-level knowledge.)
Interview	Interviewer: So you found the experience (APSI) helped you to do that? (In reference to incorporating active learning into the classroom) Participant: Yes.
Interview	During lecture when we are having some discussion, I've definitely used the turn to your small group or our partners and we talk about that and share as a class (active learning strategies). Little things like that I'm incorporating.
TEBS-Self	Pre-test score: 60; Post-test score: 82; Change: +22
BARSTL	Pre-test score: 95; Post-test score: 94; Change: -1

Note. Parentheses mark information added for clarification. Days 1,2, and 3 refer to daily reflections written during the institute. No Day 4 reflections were collected.

participant's BARSTL scores showed no significant change, with a slightly negative (-1 point) change in reformed beliefs. The progression of participant's comments about her beliefs about active learning, however, do reflect a change in the particular reformed strategy, active learning, which may indicate a focused change in only one strategy and not a generalized change in all reformed strategies. The lack of a change in the quantitative evidence would indicate that this might have been the case. It is worth noting that the BARSTL score was already quite high, which indicated this participant held largely reformed beliefs before the APSI.

I turned to Participant Two's words again as another illustration of the application of the theory of planned behavior (Ajzen, 2005), this time looking at the construct of student-centered inquiry labs (see Table 14). During the institute, this participant engaged in photosynthesis labs in an inquiry style and stated an intention to perform the photosynthesis labs with students in the inquiry style she experienced. In the participant's comments during the interview, I saw that the participant intended, in fact, to work with Herron's scale of inquiry as modified by the College Board (The College Board, 2012). The participant desired to select an appropriate level of inquiry for her class depending on her students' readiness. The statements provide evidence of several teacher behaviors, that of asking students questions and allowing them to design their labs. The participant attributed the mastery experiences with the labs at the APSI with helping to make the transfer to the classroom.

Table 14

Evidence Supporting Changes in Ideas about Inquiry Labs and Self-Efficacy in Participant Two

Data source	Participant's responses
Day 1	Appreciated learning the scale of inquiry- I will be adjusting over the course of the year based on student readiness. (Thoughts on inquiry)
Day 1	Photosynthesis lab. (What are you looking forward to using?)
Interview	So we did start the algal beads. We did the leaf disc lab too
Interview	I usually start out with a lab, and then allow the students to go a little bit deeper and design their own experiment in that aspect. So they have started realizing, oh we can ask more questions than those (the teacher) gave us originally.
Interview	They (i.e. the students) are so used to, experiments have to be done a specific way, we have to get the same results, and I'm breaking them of that habit.
Interview	I think being able to experience all, well not all, but most of the labs during the institute helped me figure out what do I need to be incorporating into my classroom
TEBS-Self	Pre-test score: 60; Post-test score: 82; Change: +22
BARSTL	Pre-test score: 95; Post-test score: 94; Change: -1

Note. Parentheses mark information added for clarification. Days 1,2, and 3 refer to daily reflections written during the institute. No Day 4 reflections were collected.

Participant 37: Scaffolding inquiry laboratories and self-efficacy. On Day One, Participant 37 was happy to find a scaffold for the inquiry labs. Participant 37 had four years of teaching experience, and was teaching AP Biology at a public high school for the first time in the fall after the institute. We had discussed Herron's levels of inquiry, as modified by the College Board (2012). The idea of working toward making the labs reach higher levels of inquiry, with an eventual goal of open inquiry, resonated with the participant. While the idea of trying to do all open inquiry labs from the beginning was not a workable situation for this participant, moving a lab from a structured level to guided level was something that seemed practical. In the follow-up interview, I saw that the participant had used this scaffolding in the classroom with guided (supported) inquiry. The participant expressed confidence that students would be successful at open inquiry in the spring semester. Participant 37 had a 17-point increase in the TEBS-Self score. Table 15 shows this participant's confidence building and the effect of this confidence on her classroom behavior. In addition to the example above, I also noted increased confidence in the participant's own words:

> Going to the summer institute saved me, I think, in teaching this class. Because before I knew a very small amount, like I said I had gone to the online training before but I really didn't know anything about teaching the class, I didn't know what my day to day was going to look like. I really didn't have a grasp of the big ideas and how to chunk this out, I had no idea how to approach test prep with the kids and I think I got really good solutions to all of those at the summer institute. (Participant 37, Interview)

Table 15

Evidence Supporting Changes in Ideas on Scaffolding Inquiry Labs in Participant 37

Data source	Participant's responses
Day 1	I really liked what you said about not making all labs open inquiry, but just trying to move them up a level. That seems much more realistic for both me and my students, and will still be a big improvement!
Interview	The kids in my district don't have very good background with the inquiry-based labs. They don't do that at the middle school level so it's really scary for them to do that...But we have started with a little supported inquiry. I'd like to do full out open inquiry second semester and I think they will be ready for that then.
TEBS-Self	Pre-test score: 73; Post-test score: 90; Change: +17
BARSTL	Pre-test score: 97; Post-test score: 100; Change: +3

Note. Parentheses mark information added for clarification. Days 1,2, and 3 refer to daily reflections written during the institute. No Day 4 reflections were collected.

Participant Three: Self-efficacy. Participant Three's reflections over three days gave me a window into the growth of confidence during the APSI, as reflected in Table 16. This participant had one year of teaching experience. On Day One this participant expressed concerns about motivating students to engage in inquiry behaviors. On Day Two, the participant showed a growing confidence in the ability to do this, and by Day Three, the participant's thoughts had become more reflective about what it means to do inquiry. This participant had a large increase in the TEBS-Self of 13 points.

Table 16

Evidence Supporting Changes in Confidence with Student-Centered Learning in Participant Three

Data source	Participant's responses
Day 1	How do I motivate general classes to do this? When I let them go they seem to get distracted quickly. (Thoughts on inquiry)
Day 1	I have tried it before, I want it to work. (Thoughts on inquiry)
Day 2	I have gained more confidence to do things I need to do. And to explain things. (Learned today)
Day 2	Needs to be done, I'm so happy/pumped to get the tools I need to become a better teacher for all of my classes. This is how I learn best, so why shouldn't I direct my students this way? (Thoughts active learning)
Day 3	It's less about the labs and more about the process of scientific inquiry. (An "Ah ha" moment)
TEBS-Self	Pre-test score: 46; Post-test score: 59; Change: +13
BARSTL	Pre-test score: 88; Post-test score: 94; Change: +6

Note. Parentheses mark information added for clarification. Days 1,2, and 3 refer to daily reflections written during the institute. No Day 4 reflections were collected.

Participant 38: Increasing student collaboration. In Table 17, Participant 38's reflections expressed a goal for the institute of increased student collaboration, an idea consistent with reform. On Day One, this participant pointed to several activities related to accomplishing that goal, including inquiry and math-science integration. Comments on Day One included thoughts about student involvement, interaction, and participation. By Day Two, the participant shared the belief that, "Active learning increases student understanding and retention" This progression from one day to the next shows movement on student-centered learning, from a need to an intention, and beliefs that progress from classroom specific ideas to thoughts about the nature of science. These statements correspond well to score increases observed in both surveys.

Table 17

Evidence Supporting Changes in Views on Student Collaboration in Participant 38

Data source	Participant's responses
Pre Institute	Tips for increasing student collaboration. (Expressed goal)
Day 1	The inquiry style of increasing student involvement in their own learning. (Looking forward to using)
Day 1	I liked the crossover lesson with statistics. It gets the students moving, provides visual assistance, requires student interaction and incorporates math skills. (Thoughts on math-science integrated lessons)
Day 1	I really enjoy the student led inquiry. It ensures more overall class participation and all students need to think about what they are doing.
Day 2	Active learning increases student understanding and retention.
TEBS-Self	Pre-test score: 73; Post-test score: 78; Change: +5
BARSTL	Pre-test score: 89; Post-test score: 96; Change: +7

Note. Parentheses mark information added for clarification. Days 1,2, and 3 refer to daily reflections written during the institute. No Day 4 reflections were collected.

Participant 36: Self-efficacy. Reflections from Participant 36 captured emotions relating to increased confidence with inquiry labs. During the APSI, this participant highlighted her experiences with a modeling event followed by a mastery event while working with the leaf disk lab as inquiry. The participant expressed that she had more confidence after these experiences. She also mentioned that she intended to do this lab as an inquiry experience with her students. This participant showed a large increase in both the TEBS-Self (9.5 points) and the BARSTL (11 points). Her comments provide support for the assertion that these activities were associated with these score increases. See Table 18 for detailed quotes.

Table 18

Evidence Supporting Changes in Confidence to do Inquiry Labs in Participant 36

Data source	Participant's responses
Day 1	I liked how we followed along with you to learn how the procedure works, brainstormed & discussed all of the variables that could be changed and THEN allowed us to investigate our own question. A great way to allow for inquiry even though you needed to teach the lab skills necessary. (While discussing the leaf disc inquiry lab)
Day 1	I think one reason I shy away from inquiry is that the students don't have the skills but now I have learned ways to combat that!
Day 1	I'm looking forward to using the leaf disc lab as inquiry.
TEBS-Self	Pre-test score: 61; Post-test score: 70.5; Change: +9.5
BARSTL	Pre-test score: 92; Post-test score: 103; Change: +11

Note. Parentheses mark information added for clarification. Days 1,2, and 3 refer to daily reflections written during the institute. No Day 4 reflections were collected.

Participant 34: Self-efficacy. Although the increase in self-efficacy scores on the TEBS-Self for the entire group was statistically significant, some individual participants showed a decrease in self-efficacy score. Participant 34 expressed a goal of increasing knowledge of techniques related to inquiry. Day Two reflections indicated an appreciation for active learning but a lingering concern about maintaining control. My sense is that this participant must be able to give up some control in order to have confidence in her ability to successfully facilitate active learning, including inquiry, in the classroom. This participant's ambiguity regarding her own abilities is reflected in her statements, as well as the decreases I observed in her self-efficacy scores on the TEBS-Self (see Table 19).

Table 19

Evidence Supporting Statements Showing Changes in Self-efficacy in Participant 34

Data source	Participant's responses
Pre-Institute	As only a second year AP teacher, I hope to learn more methods, techniques and skills in teaching an AP class with an increased inquiry based approach.
Day 2	It is great. A work in progress. But I am still learn(ing) how to maintain control and keep the focus. (Thoughts on active learning)
TEBS-Self	Pre-test score: 85; Post-test score: 76.5; Change: -8.5
BARSTL	Pre-test score: 88; Post-test score: 90.5; Change: +2.5

Note. Parentheses mark information added for clarification. Days 1,2, and 3 refer to daily reflections written during the institute. No Day 4 reflections were collected.

Participant 31: Collaboration in inquiry. Participant 31 showed a deepened understanding of collaboration as part of the inquiry process. While the participant indicated support of inquiry lessons on Day One, this support was extended on subsequent days to include an appreciation and value in the viewpoints of others. These statements reflecting increasingly reformed beliefs helps explain the large, 15-point increase in the BARTSL**.** See Table 20 for the related reflection thread.

Participant 21: Self-efficacy. Quantitatively, Participant 21 demonstrated a large increase in self-efficacy scores on the TEBS-Self. (This participant did not have a BARSTL score.) A corresponding thread of qualitative data (see Table 21) reflects increased confidence regarding inquiry throughout the APSI experience. Day One comments reflect positive attitudes and hope that the participant can effectively orchestrate inquiry-based experiences in the classroom. Comments in days Two and Three reflect the participant's interest in reformed assessment strategies. I include this participant's comments, in particular, because of the connection between increased understanding of student-centered assessment practices and her boosted confidence in the ability to succeed with inquiry in the classroom.

Table 20

Evidence Supporting Changes in Beliefs about Collaborative in Student Centered Learning in Participant 31

Data source	Participant's responses
Day 1	Inquiry lessons are a must, and need to be engaging throughout the process.
Day 2	I actually had a couple of "ah ha" moments today. The first was when I realized that the reaction from the algal balls was continuous & the colors were different because they were cycling @ different rates due to high exposure, number of balls per tube, etc. I know this, but I hadn't connected the dots until the group started talking and sharing ideas.
Day 2	That everyone knows something that you don't & that we are always learning each day.
Day 3	The awareness that was brought to everyone's attention was that I understand how the students feel when they cannot grasp the concept of the lab right away, but after the data is collected. It was a powerful awareness.
TEBS-Self	Pre-test score: 76; Post-test score: 74; Change: -2
BARSTL	Pre-test score: 82; Post-test score: 97; Change: +15

Note. Parentheses mark information added for clarification. Days 1,2, and 3 refer to daily reflections written during the institute. No Day 4 reflections were collected.

Table 21

Evidence Supporting Changes in Confidence Regarding Inquiry and Assessment in Participant 21

Data source	Participant's responses
Day 1	As I grow to understand how to manage time effectively & empower students w/more freedom by allowing greater access to materials during inquiry lessons, I am becoming more of fan of inquiry.
Day 2	Leaf disc lab assessment strategies→ can apply to all labs. i.e. Based on photo above, what ? may researcher have been asking…(Learned today and will remember)
Day 3	How to assess a lab w/posters & student questioning of each groups presentation. (An "Ah ha" moment)
TEBS-Self	Pre-test score: 76; Post-test score: 89; Change: +13
BARSTL	Pre-test score: N/A; Post-test score: N/A; Change: N/A

Note. Parentheses mark information added for clarification. Days 1,2, and 3 refer to daily reflections written during the institute. No Day 4 reflections were collected.

Participant 28: Self-efficacy in statistics. Table 22 shows a growing confidence with statistics for Participant 28. This participant's thread began with a desire for more data analysis as a workshop goal. Overall, I found that occasional collaboration with the AP Statistics teachers (attendees in a separate APSI workshop) increased participants' confidence and beliefs about the importance of activities integrating biology and statistics. This participant noted, in particular, the use of statistics in the classroom. The participant's comments indicated a progression of increased confidence, aligned with the increase in TEBS-Self, but also showed a belief about the value of conceptual understanding through math-science integration.

Table 22

Evidence Supporting Changes in Confidence with Statistics in Participant 28

Data source	Participant's responses
Pre-Institute	Integration of data analysis (outside of lab work). (Goal)
Day 1	Really looking forward to using the statistics activities we completed today. Statistics are definitely a weaker area of mine.
Day 1	Loved the opportunity to work with our AP Stats buddy. .
Interview	That was really helpful. I would say definitely say the math, being able to tie that in with the statistics and stuff that's been super helpful for me. (Something from the summer you have used) Because I don't have any, my background is terrible, I knew Chi-Square, I can do Hardy Weinberg, because you know you can kind of teach yourself that stuff, but then standard deviation …deer in the headlights right? So being able to just kind of use that math and have them come in while we had the data in front of us and practice that, it's huge. It's been really helpful. That has been definitely something that I have used.
TEBS-Self	Pre-test score: 66; Post-test score: 74; Change: +8
BARSTL	Pre-test score: 85; Post-test score: 99; Change: +14

Note. Parentheses mark information added for clarification. Days 1,2, and 3 refer to daily reflections written during the institute. No Day 4 reflections were collected.

Summary: Association of Survey Scores with Participants' Statements.

Results to Questions One and Two in Section One set up the analysis that followed in Question Three. Results from the content analysis of a pre-APSI survey indicated the participants' needs centered on preparation, science reform, and self-efficacy. Pre-post APSI comparisons indicated that participants' attitudes toward science reform and their self-efficacy had significantly changed toward higher scores on both instruments. Post-hoc analysis indicated differences in participants' responses due to experience, with more positive changes in science reform observed in more experienced teachers and more positive changes in self-efficacy observed in less experienced teachers, but with a positive shift in the overall mean for both measures.

In Question Three, I used qualitative data from individual participants to elaborate the numerical changes I had observed in their TEBS-Self and BARSTL scores. In this way, I connected the changes in self-efficacy and reformed beliefs about science teaching and learning from the survey data with real expressions from teacher participants to learn more about changes indicated in the quantitative data.

Qualitative data collected pre-, during-, and post-APSI provided: (a) evidence of personal outcomes for APSI learning before the workshop; (b) beliefs, and belief changes and expressions of participants' intentions to perform reformed teaching behaviors during workshop participation; and then (c) participants' explanations of enactments in their classroom in interviews I conducted with them during the school year. When post-APSI interview data were available, I used data sets full of before-, during-, and post-APSI comments from participants to show a full progression of change, which provided evidence that survey results indeed did reflect changes in participants' classroom behaviors. Even though incomplete datasets without the interview data could not provide evidence of behavioral teaching changes, I was able to use these incomplete sets to substantiate intentions to change, which theory (Ajzen, 2005) indicates would precede actual behavioral changes. The interview data supports theory, therefore, affirming that participants' intentions were largely followed by the implementation of teaching behaviors in their classrooms. I am comfortable in predicting that, even when evidence of actual classroom enactments were lacking, intentions expressed during participants' experiences during the APSI would lead to reformed behaviors in the classroom.

With these findings in mind, I then turned to a question about the participants' reflections of the workshop in general and on the impact in their classrooms. Interview data allowed me to examine the alignment of participants' self-reported beliefs, intentions, and behaviors with theory. This examination is the subject of Section II.

Section II: Transfer to the Classroom

Research Question Four: The Interviews

What were the participants' perceptions, beliefs, intentions and behaviors about the institute workshop after returning to the classroom? Question Four is the third research question within a sequence of three questions focusing on change. In Question Two, I used participants' responses to pre-and post-Institute questionnaires to establish an association between participants' engagement in the institute and changes in their beliefs. I used quantitative methods to indicate statistically significant changes in participants' self-efficacy beliefs and in their beliefs regarding reformed practice. For Question Three, I used qualitative methods to triangulate the results from the quantitative findings from Question Two. I compiled statement threads from participants' written responses and interview transcripts to confirm progressive changes in participants' beliefs, which I also associated with data from their questionnaire responses. Basically, I found that beliefs participants had brought to the APSI progressively changed throughout the APSI, thus confirming the quantitative changes I had observed in participants' scores on the questionnaires. Question Four reflects my desire to learn more about the transfer of newly changed beliefs after participants' attempts to implement new ideas about reform in their own AP classrooms. I wanted to know two things: (1) whether participants' expressions reflected that they still held reformed beliefs, intentions, and behaviors, and (2) whether participants' descriptions of their current teaching practices could be traced back to their APSI experiences.

Research design. To answer Question Four, I conducted semi-structured interviews with nine participants to examine how the activities and strategies from the APSI had impacted participants' perceptions, beliefs, and intentions, and, by extension, their behaviors with students in their classrooms. I used a directed coding scheme (Hsieh & Shannon, 2005) aligned with theory to analyze participants' interview statements, similar to the qualitative analyses processes I employed in answering Question Three.

The informants. I purposefully selected interview participants on the basis of changes observed in participants' scores on the BARSTL (Sampson et al., 2013) or on the TEBS-Self (Dellinger et al., 2008). I separately rank-ordered participants on the basis of the pre-post-institute score differences for the BARSTL and TEBS-Self. Participants were divided into two groups by the location of the APSI. I invited participants with the largest differences in each group, separately for each instrument, to participate in the semi-structured interviews. While my plan was to interview five participants from each site, with a split between BARSTL and TEBS-Self**,** I was able to schedule and conduct only nine interviews within the October to March interview window. Of these nine, three of the interviewees had large increases in the BARSTL instrument and six had large increases in the TEBS-Self. Four of the participants were from the first workshop location and five were from the second.

The interviews. I made scheduled interviews by telephone or in person with each of the nine participants. The questioning route I developed for the semi-structured interview may be found in Appendix D. I conducted three interviews in person and six by telephone, with an average interview length of about 26 minutes and a total interview time of three hours and 52 minutes. I received permission from all participants to audio-record their interviews. To thank each for his or her time, I offered an hour of my consulting time to each interviewee. To prepare the interview data for analysis, I personally transcribed the audio-recorded interviews and assigned pseudonyms for the interview participants. Details regarding the interviews are summarized in Table 23.

Table 23

Interview Lengths and Selection Criteria

Participant Number	Pseudonym	Length (min:sec)	Selection Basis
28	Theresa	44:10	BARSTL
22	Sonya	30:53	BARSTL
04	Cody	18:44	BARSTL
30	Elizabeth	31:02	TEBS-Self
03	Julie	27:38	TEBS-Self
35	Angie	25:42	TEBS-Self
37	Kerry	21:43	TEBS-Self
02	Leah	17:40	TEBS-Self
33	James	14:08	TEBS-Self
	Average Interview Duration	25:44	

The Coding Scheme

Grounded in theory. To answer Question Four, I used the same coding scheme for identifying threads in the data as I used for Question Three, which I summarized here. I used the directed approach (Hsieh & Shannon, 2005) to content analysis in which theory is used to determine the initial codes to be applied to the segments after I had identified them in the interview transcripts. Furthermore, I used the two theories for coding in the same way as I used them in Question Three, nesting codes derived from Bandura's (1977) theory of self-efficacy within codes for Ajzen's (2005) theory of planned behavior. See Appendix E for a schematic.

Coding Overview. I allowed theory to reign supreme in my coding scheme, which I used in analysis of Question Four. I recognized the complexity of the coding scheme, and the potential for confusion due to the intersection of multiple theories and concepts. To aid my readers, I have provided an overview of the coding scheme.

There were three levels of coding, and I applied the coding scheme to each identified segment, as one would follow a flow chart, resulting in three coding assignments per segment. Level One was informed by Ajzen's (2005) theory of planned behavior, and Levels Two and Three were informed by Bandura's (1977) self-efficacy theory and concepts from the BARSTL (Sampson et al., 2013). Before I described each coding level, I have provided a box within a box figure to help the reader locate the coding level within the overall coding scheme. The entire coding scheme may be found in Appendix E. The use of many related codes and terms was potentially confusing as well, so I have provided a clarifying table for Level One keywords (see Table 24).

Level One coding. I applied three levels of coding after segmenting the nine transcripts. The location of Level One coding, within the coding scheme, is found in Figure 12. In Level One coding, I derived codes from Ajzen's (2005) theory of planned behavior to identify the five first level codes: (1) Behavioral Belief (BB; including related attitude), (2) Normative Beliefs (NB; including and encompassed within the subjective norm), (3) Intention (INT), (4) Behavior (BEH), and (5) Control Belief (SE; encompassed within perceived behavioral control which is equivalent to self-efficacy). Figure 13 contains details of this initial Level One coding. Category codes one, two, and five combine beliefs and associated attitudes. These attitudes result from evaluation of the beliefs. For this study I did not need to separate these determinants. Each code was used for both belief and related attitude. See Table 24 for additional clarification.

Table 24

Explanation of Keywords used in Level One of Coding Scheme

Keyword	Notes and Application in this Study	Theory
Behavioral Beliefs (BB)	Beliefs about reformed teaching behaviors. When behavioral beliefs about reformed teaching behaviors are combined with an individual's evaluation of the likely outcome of these behaviors, we see the attitude toward the behavior.	TPB (Ajzen, 2005)
Attitude toward the Behavior	The personal attitude about a reformed teaching behavior is a combination of an individual's behavioral beliefs about reformed teaching and an individual's own evaluation of the benefits of the behavior.	TPB (Ajzen, 2005)
Normative Beliefs (NB)	An individual's belief that people important to them think they should (or shouldn't) teach in a reformed manner.	TPB (Ajzen, 2005)
Subjective Norm	A combination of an individual's Normative Beliefs about reformed teaching with their motivation to comply with the related social pressure.	TPB (Ajzen, 2005)
Control Beliefs	Beliefs an individual holds about whether or not factors exist that will help or hurt their realization of teaching AP Biology.	TPB (Ajzen, 2005)
Perceived Behavioral Control	The individual's perception of the difficulty or ease with which they can carry out the behavior, teaching AP Biology in a reformed manner.	TPB (Ajzen, 2005)
Self-Efficacy (SE)	Equivalent to perceived behavior control according to Ajzen (2002) who notes control beliefs and perceived behavioral control may be considered as one depending on the study.	Self-efficacy (Bandura, 1977)

Note. The theory of planned behavior is abbreviated TPB. The keywords are from Ajzen (2005) and Bandura (1977).

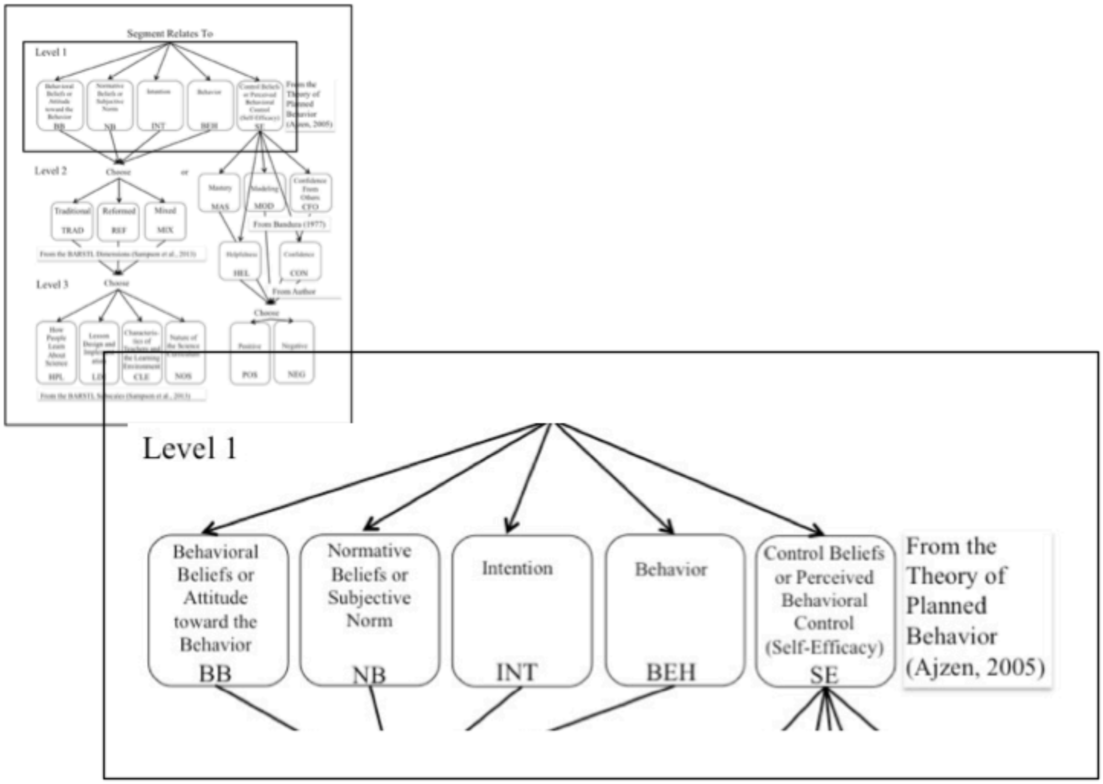

Figure 12. Location of Level One codes within entire coding scheme. See Appendix E for full diagram.

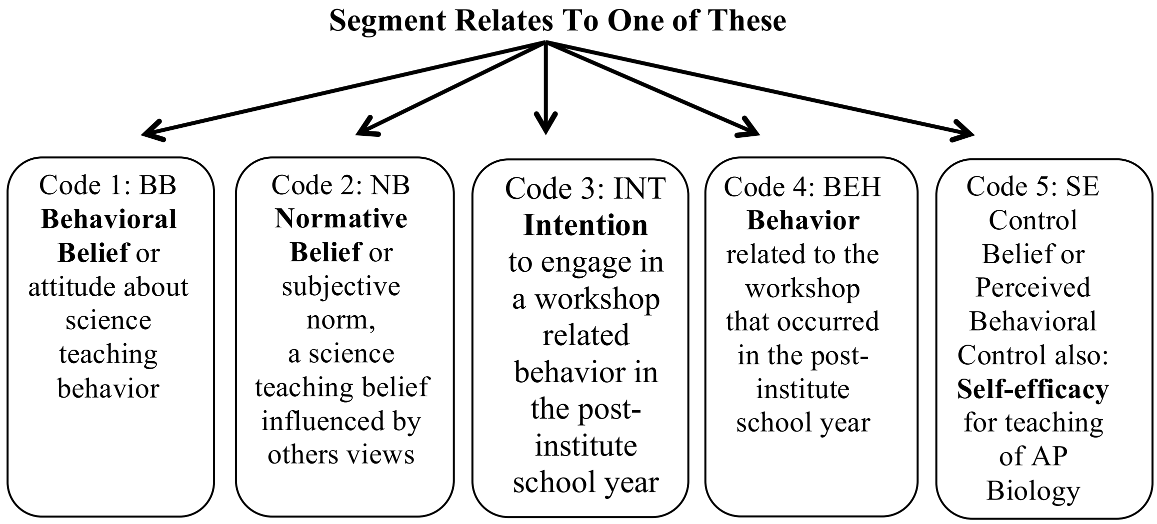

Figure 13. Level One Coding. Five codes used for the initial directed coding scheme based on the theory of planned behavior (Ajzen, 2005). Code five (SE) was informed by Ajzen's theory and Bandura's theory of self-efficacy. I used working codes, appearing in capital letters beside the code number, for table sorting purposes.

Level Two coding. The location of Level Two coding, within the coding scheme, is found in Figure 14. After coding all instances of segments related to beliefs, intention, and behavior in the first round of coding, I then subjected each segment to a second round of coding. In the second round, I revisited segments assigned with one of these four codes: (1) Behavioral Belief (BB), (2) Normative Belief (NB), (3) Intentions (INT), or (4) Behavior (BEH). (Note: I revisited the code Self-efficacy (SE), separately, due to the dual origins of the code from two theories.) In this second round of coding for segments coded BB, NB, INT, and BEH, I coded each as Reformed (REF), Traditional (TRAD), or Mixed (MIX) depending on the perspective implied in the segment.

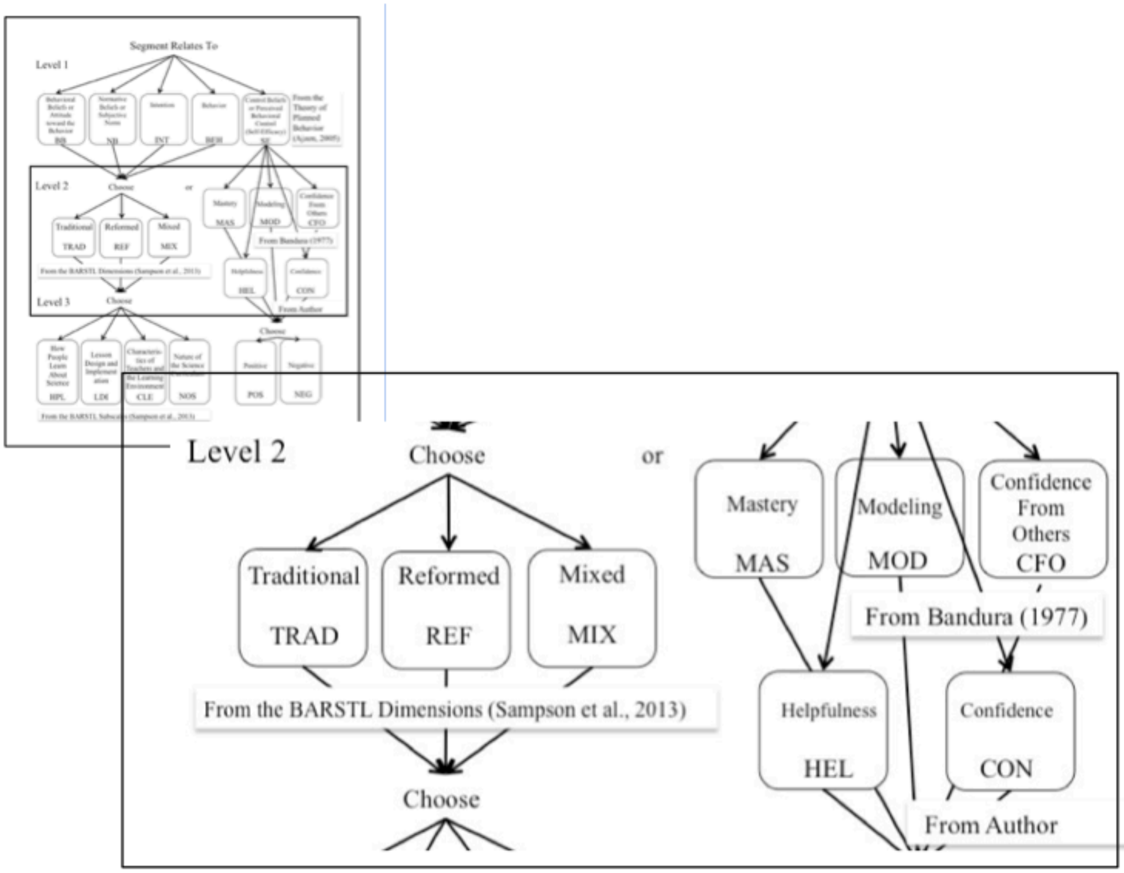

Figure 14. Location of Level Two codes within entire coding scheme. See Appendix E for this full diagram.

These three Level Two codes were based on the BARSTL dimensions described by Sampson, et al., (2013, see Table 25).

Regarding Self-Efficacy. I treated the category Self-efficacy (SE) uniquely. To code the single remaining element in Ajzen's theory of planned behavior, I turned to a second theory, Bandura's self-efficacy theory (1977). Ajzen (2002) notes that self-efficacy is analogous to perceived behavioral control*,* and though there is the control element as well, a researcher may be justified in considering them as one as I did here. I applied codes derived from Bandura's theory of self-efficacy (Bandura, 1977) to segments that related to control belief or perceived behavioral control. Bandura's research led to the identification of four types of experiences that can increase self-efficacy. I have used three of these experiences in my coding scheme: (1) Mastery Experiences (MAS), (2) Modeling (MOD), and (3) Confidence Gained from the Input of Others (CFO). As several statements did not provide enough detail to permit coding into one of these three categories, I created two additional codes, Helpfulness (HEL) and Confidence (CON) for general statements related to self-efficacy.

Level Three coding. The location of Level Three coding, within the coding scheme, is found in Figure 15. In the third level of coding, I first considered the segments coded based on the BARSTL dimensions (Traditional, Reformed, or Mixed) in Level Two. I applied a code reflecting assignment to one of the four subscales from the BARSTL (see Table 24). For the remaining Level Two codes, related to Self-Efficacy (SE), the final coding step was to assign the nature of the experience as Positive (POS) or Negative (NEG). A schematic of the entire coding scheme may be found in Appendix E. I used a word table to record the codes, making it convenient to sort the data in various ways. For an example of entries in the coding table see Table 26. (Note for Question Four only post-institute interview data was used.)

Table 25

Dimensions of Traditional and Reformed Minded Beliefs for Each Subscale of the BARSTL (Review)

BARSTL Sub Scale	Traditional Perspective	Reformed Perspective
How people learn about science	Compared with "blank slates." Learning is accumulation of information.	What students learn is influenced by their existing ideas. Learning is the modification of existing ideas.
Lesson design and implementation	Teacher-prescribed activities. Frontal teaching-telling and showing students. Relies heavily on textbooks and workbooks.	Student-directed learning. Relies heavily on student-developed investigations, manipulative materials, and primary sources of data.
Characteristics of teachers and the learning environment	The teacher acts as a dispenser of knowledge. Focus on independent work and learning by rote.	The teacher acts as facilitator, listener, and coach. Focus on learning together and valuing others ideas and ways of thinking.
The nature of the science curriculum	Focus on basic skills (foundations) Curriculum is fixed. Focus on breadth over depth.	Focus on conceptual understanding and the application of concepts. Curriculum is flexible, changes with student questions and interest. Focus on depth over breadth.

Note. Adapted from "Development and Initial Validation of the Beliefs About Reformed Science Teaching and Learning (BARSTL) Questionnaire" by V. Sampson, P. Enderle, and J. Grooms, 2013, *School Science and Mathematics, 113*(1), p. 6.

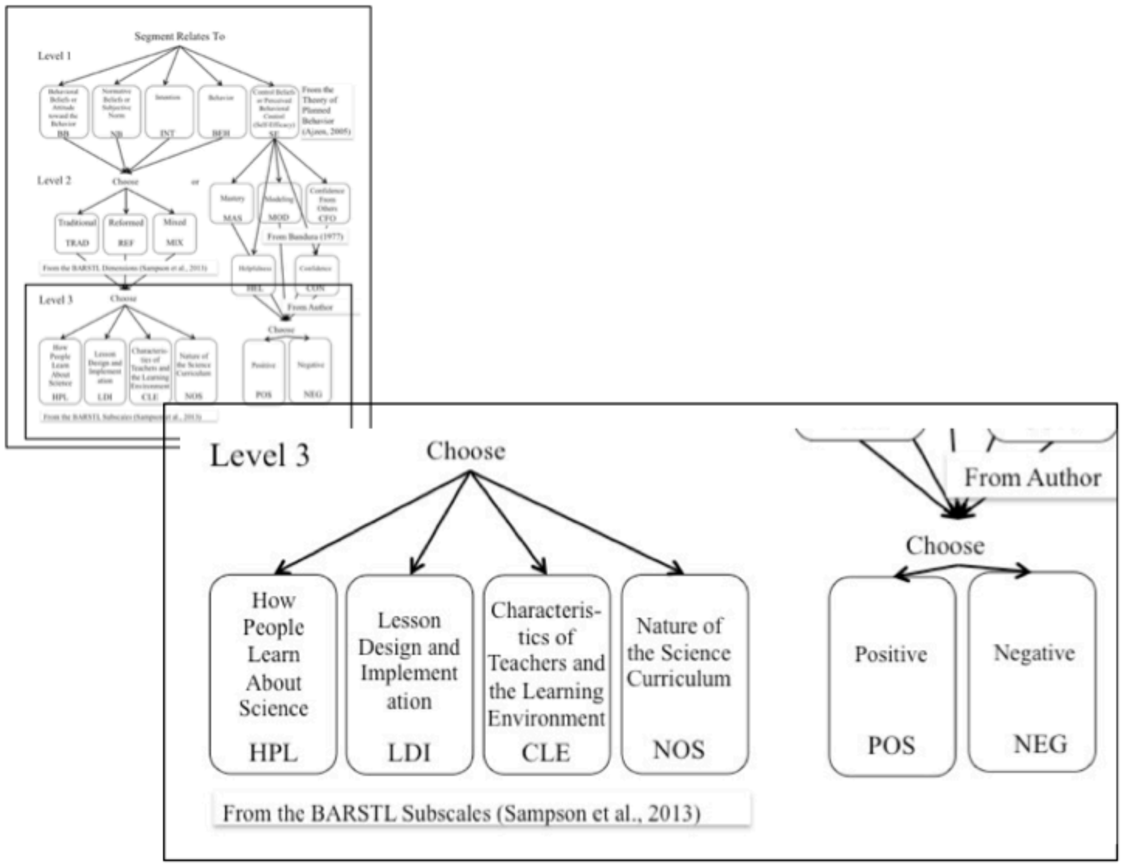

Figure 15. Location of Level Three codes within entire coding scheme. See Appendix E for this full diagram.

Table 26

Sample Segment of Word Table Used for Coding Then Sorting

Segment Identifiers			Segment	Code		
P	D	Q		C-1	C-2	C-3
1	2	4	Really throwing ideas off of one another during the algae beads discussion and conversation. We all have certain strengths as far as science backgrounds go so it was good to get certain perspectives.	BB	REF	CLE
2	4	I	During lecture when we are having some discussion, I've definitely used the turn to your small group or our partners and we talk about that and share as a class. Little things like that I'm incorporating. They are always in small groups for lab.	BEH	REF	CLE
2	4	I	Sure, I think being able to experience all, well not all, but most of the labs during the institute helped me figure out what do I need to be incorporating into my classroom, first of all	SE	MAS	POS

Note. Column "P" is the participant number. Column "D" refers to day; (a) 0 is a pre-institute comment, (b) 1-3 are institute daily reflections from days 1 (Monday), 2 (Tuesday), or 3 (Wednesday) respectively, (c) 4 refers to data from a post-institute interview. Column "Q" refers to the question number; (a) 1-11for daily reflections questions, (see Appendix C), or the letter "I" if from an interview. Columns C-1 through C-3 are coding columns for code levels 1-3. (See Appendix E for details; code abbreviations also appear in this appendix.)

Interview Results

My questions in the semi-structured interview (see Appendix D) provided participants with an opportunity to contemplate their summer institute experience in terms of their current teaching situation. I wanted to know two things about the ultimate outcomes associated with participants' engagement in the APSI. First, were they still holding the reformed beliefs and intentions indicated at the end of the APSI? And second, could the description of their current teaching practices be traced back to their APSI experiences?

According to the theory of planned behavior (Ajzen, 2005) an individual's beliefs are foundational in predicting his/her behavior. Ajzen identifies three types of beliefs: (1) behavioral, (2) normative, and (3) control. These beliefs form the basis for an individual's attitudes. Ajzen theorizes that a progression occurs from an individual's changes in beliefs to his or her changes in attitudes, which predict an individual's intentions to behave in a certain way. Continuing with the progression, intentions are prerequisite of behaviors. In the qualitative interview data, I found examples of these progressions experienced by participants, from beliefs and attitudes, to intentions, then to behaviors in the classroom.

I first assigned the interview segments to the appropriate Level One code based on the theory of planned behavior (Ajzen, 2005). For the segments within each separate Level One code, I discussed their assignment to Level Two and Three codes. These secondary and tertiary levels of coding reflected one of these: (1) dimension of beliefs (Traditional, Reformed, or Mixed) in one of the four BARSTL subscales, or (2) a

Positive or Negative value associated with an experience that affects self-efficacy in the teaching of AP Biology. I will discuss the results of these analyses next.

Behavioral beliefs. Behavioral Beliefs, and the attitudes related to them, were coded together. Though my participants' comments reflected a range of beliefs and attitudes about science teaching and learning from traditional to reformed, I coded most of their comments (77%) as reformed in Level Two coding. Over half of the Behavioral Beliefs comments in the BARSTL subscale How People Learn (HPL) reflected a reformed perspective. Participants' comments revealed attitudes about student learning that involved modifying and building on ideas, learning from mistakes, and reflecting on learning. For example, Theresa commented about working with students as they developed inquiry skills, and the struggle students have accepting things that don't work out as they expect. She helped them see the value of failure, her comment starting with her students' concern for a "failed" lab:

> It didn't turn out, it didn't turn out, and getting them away from that, and that's OK, what did you learn by doing that? What would you do differently? That's the point. It's ok. (Participant 28, Interview)

Other comments reflecting reformed beliefs in the subscale HPL also centered on practices used at the APSI. These included repeating inquiry labs as ideas changed, and using rubrics to evaluate and modify thinking. I definitely saw the APSI connection between these comments as I reflected on the mastery experience of Theresa and her peers as they, too, learned from mistakes as they struggled with the photosynthesis lab I presented to them during the APSI.

Some comments reflecting Behavioral Beliefs relayed concerns over students' background knowledge and their lack of retention from the prior course in biology. These participants' comments did not focus on reformed teaching, such as eliciting prior knowledge and identifying misconceptions, or any other ways to alleviate their concerns. Instead, these participants expressed frustration about the state of knowledge students brought into the course. I saw these comments as reflecting a traditional perspective of science learning as accumulation. In these cases, the participants shared the perspective that students' accumulation of prior knowledge was insufficient.

Somewhat contradictory comments were indications that people are indeed complicated, often holding views that are not purely traditional or reformed. Theresa, for instance, saw the value of learning from mistakes in the inquiry lab. A second comment, however, reflected her lack of conviction that this strategy could be successfully applied elsewhere in the course:

> I'm having them do test corrections to help with that, but I'm not…I mean I think it's helping a little but I'm not totally sure it's helping them get better. Like I think it's helping them go, oh I think I see what that's wrong, but I don't know if it's helping them for next time. (Participant 28, Interview)

My reflections on this particular finding are a bit contradictory as well. While I coded the majority of HPL comments as indicating the Reformed perspective, the balance of mixed to traditional comments in this subscale suggested to me that HPL is an area with opportunity for growth in future institutes.

After the APSI, 72% percent of the comment segments from participating teachers in the category Lesson Design and Implementation (LDI) were coded as Reformed. I coded none of the LDI statements as purely Traditional. As participants adjusted to a more student-centered approach some still held some traditional views, but these views were blended with reformed views. Seven of 18 comments, 28%, were Mixed. Participants provided many statements consistent with a belief in student-directed learning and student-developed investigations, including the importance and use of inquiry labs in the classroom. For example, Elizabeth shared how she talked to students about student-directed learning:

> Don't stress out, just try, ask me questions, don't give up, I just want you to participate. The worse that can happen is that you will have a wrong answer; you know your grade is not dependent on it. (Participant 30, Interview).

Overall, the interviews revealed that participants largely believed in student-centered instruction, even though some were conflicted. While they supported this reformed pedagogy, they were still concerned about translating it into actual teaching behavior. I coded statements showing evidence of internal conflict as mixed. For example, Julie held the traditional view that students needed notes from her for understanding, but she also saw this as a conflict as it took time away from other activities she valued that developed critical thinking. She says; "Most of them need that [notes in class] to understand, but then I feel like I'm spoon-feeding and not having enough time to develop the critical thinking" (Participant 3, Interview).

The dimensions of the reformed perspective for the sub-scale code, Characteristics of Teachers and the Learning Environment (CLE), revolved around teacher as facilitator and coach, student collaboration, and mutual respect (Sampson et al., 2013). I found that the value participants gave to student collaboration was quite high, based on the frequency of mention. Participants mentioned collaboration between students, classes, and even between schools. One participant worked with another class in order to have enough participants for an activity from the APSI. Two other participants, Elizabeth and Angie, valued the collaborative aspect of learning science. Elizabeth said, "Yeah, and that's something I have noticed in any subject, I can be saying the exact same thing, but if the person next to them says it they learn it" (Participant 30, Interview). Teachers often saw their role as that of facilitator, coordinating student discussions, presentations and inquiry labs, while students worked with and learned from others. Theresa talked about her students presenting lab results in a poster format to peers and said, "That was kind of exciting to listen to them talk about their learning rather than just read it" (Participant 28, Interview).

While the reformed perspective predominated, not all beliefs coded in the subscale CLE were reformed. Out of 36 comment segments, 30 reflected the Reformed view, one was Mixed, and five were Traditional. One participant shared a traditional perspective as she mentioned a preference for some individual teacher-prescribed work, particularly on-line tutorial work assigned as homework (this without follow-up classroom discussion). She saw this as a way to deal with classroom realities of students missing class sessions. This same participant expressed her concern that collaborative work doesn't necessarily translate into classroom test success. Other comments reflected beliefs regarding students' desire to have knowledge dispensed by the teacher and participants' struggles with this.

I found teacher beliefs expressed in the category Nature of Science (NOS) to be 83% Reformed. For instance, Theresa, expressed her newfound comfort with teaching in a more conceptually with, "Just give them lots of data to look at, give them the big stuff, [make them] think a lot and make them write a lot, and they will be fine" (Participant 28, Interview). Other teachers recognized the importance of building conceptual understanding, though it might be something they were still working on. This was seen in Sonja's reflections when she said, "One concern that I feel I need to improve on is trying to get them to understand how all the big ideas pull together" (Participant 22, Interview).

Some participants discussed their experiences on a Pre-AP team where they had a very fixed curriculum and were expected to be on the same page as all the other teachers of the course. I felt that this traditional viewpoint should be examined in light of the fact that the Pre-AP course serves as a feeder course for AP Biology in some parts of the country, particularly as a fixed curriculum can make it difficult for teachers to respond to the needs of the students. The transfer of students trained under this teaching style, to a more responsive AP Biology course, could be problematic.

The interview data show behavioral beliefs and attitudes are still reformed after the institute. Ninety-two segments from the interview transcripts were coded as relating to Behavior Beliefs and associated attitudes. Of these segments, 71 were coded as

Reformed (77%), 11 as Mixed (12%), and ten as Traditional (11%). The category containing the largest number of coded segments was Reformed CLE at 30.

Normative Beliefs. An individual's Normative Belief is a persons' perception that people significant to him think he should or should not perform a behavior. When the desire to comply is factored in, we have the subjective norm. I coded twenty-two comments from the interviews as NB in which I grouped the normative belief and subjective norm. In this code category I included 13 comment segments as Reformed, three as Mixed, and six as Traditional. I found these comments to be longer and more complex than those seen in any of the other categories.

As the workshop facilitator, I was a source of normative beliefs for some participants including Elizabeth who valued knowing I believed in the student-centered behaviors I was sharing and that they had worked for me. Julie talked about the role of others at the institute as a source of normative beliefs; "I really liked the [at the time of the institute] networking with the people at my table and sharing ideas and that sort of thing. It's always nice to hear other people's ideas and opinions." (Participant 3, Interview)

I also found that the student-centeredness of the College Board AP Biology curriculum was a big source of normative belief (as well as comfort) to participants like Elizabeth who appreciated knowing she was *supposed* to be teaching in a reformed way. Her statement, "Ok cool, like I'm not super far off base" shows the importance she placed on the normative beliefs she derived from the AP program norms (Participant 30, Interview). Kerry also mentioned the College Board's reformed perspective, this time in the subscale NOS, with this comment, "I'm also trying to be cognizant of the fact that they want it to be more in-depth learning, so maybe less breadth of learning and going deeper into it" (Participant 37, Interview).

I found an additional source of a normative belief for participants came from their students. One teacher talked about the value of building a reputation for the course where the expectations would be known to students. She felt this would eventually lead to a better fit between her expectations and those of her students. Alternately, negative normative beliefs that originated from students could be problematic for teachers trying to increase reformed teaching behaviors in the classroom. Some teachers reported complaints and concerns from students about student-centered learning.

I found the normative beliefs teachers wanted most were those from their peers, and *it was often perceived as missing*. Participants wanted to know how their beliefs lined up with the beliefs of others teaching AP Biology, and they asked me in the interviews how others were handling pacing, notes, and student-centered learning. I heard from several teachers who felt they were behind and wanted to know if others were behind as well. The need for a supportive normative belief was especially acute when participants were struggling with the reformed perspective. Julie wanted advice on getting students to complete work outside of class. Sonja asked, "has anyone said anything about the kids not wanting to try as hard as they should be to think?" (Participant 22, Interview).

The institute peer group was influential during the workshop week but this was a temporary situation. Some participants recognized the importance of peer support and tried to fill their need for this source of a normative belief by setting up a Facebook page for participants. The use of social media was an effort to provide the missing normative belief, and served as a source for viewpoints and opinions of peers while it provided help and encouragement. This was very important to the new AP Biology teachers because they are often the only AP Biology teacher in the school.

The conflict between ideas of the participating teachers and other teachers in their schools illustrated to me that normative beliefs held a lot of power in terms of negative effects on student-centered learning, even the power to made the student-centered behaviors of teachers less likely to occur. We see Theresa describing the situation at her school:

> We have other teachers, maybe they have been teaching for a while, and it is very strictly like lecture, take my notes, exactly like I have them, memorize the organization of how this is, and when you take a test, these are the things you need to know. It's not, it's a lot of information and a lot of note taking, because I hear that stress level on students, but it's not a lot of critical thinking. (Participant 28, Interview)

Alternately, some participants were influenced by reformed normative beliefs at their schools, such as in James' case; "My school wanted me to do the AP training… they told me they wanted me to use it to guide thinking." (Participant 33, Interview)

Control beliefs/self-efficacy. Again using the principles of directed content analysis (Hsieh & Shannon, 2005), I used theory as the source for codes to categorize statements having to do with control or self-efficacy. Bandura (1989) described self-efficacy beliefs as, “People’s beliefs about their capabilities to exercise control over events that affect their lives” (p. 1175). Dellinger et al. (2008) refined self-efficacy for the teaching situation as, “Teacher self-efficacy beliefs can be defined as a teacher’s individual beliefs in their capabilities to perform specific teaching tasks at a specified level of quality in a specified situation” (Dellinger et al., 2008, p. 752). For this study, I am defining self-efficacy as participants’ beliefs in their abilities to teach AP Biology successfully in their schools. The theory of self-efficacy identifies four sources of information that feed into self-efficacy: (a) mastery (performance), (b) modeling (vicarious), (c) information from others (verbal persuasion), and (d) physiology (Bandura, 1977). I used the first three as codes for statements relating to self-efficacy.

After I coded a statement as being concerned with self-efficacy, I also coded it as Mastery, Modeling, Confidence from Others, Help, or Confidence. I added the categories Help and Confidence to code statements that could not be assigned to Bandura’s categories due to lack of detail. Finally, I further coded all statements as Positive or Negative. These codes and examples of topics used as context for the codes are in Table 27. The theory of self-efficacy permitted me to predict positive changes in self-efficacy would result from mastery experiences, modeling experiences, and verbal persuasion (Bandura, 1977). In my case these changes would be increased confidence to teach AP Biology. Increased self-efficacy was important in the preparation for teaching AP Biology because, “efficacy expectation 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" (Bandura, 1977, p. 194). Preparing to teach a course at this level requires significant, sustained effort.

Participants made statements coded as a mastery experience from the APSI eighteen times and all of these statements were positive. The experiences mentioned were inquiry labs, integrated activities using statistics, and presentation of lab results to peers. Modeling experiences were favorably perceived, with 75% positive comments. When comments about modeled activities were negatively coded they showed lack of confidence, such as Sonja's thoughts on questioning: "I thought your inquiry was good, and I always liked the way you would say, what if this, or what if that, but I've not done just a great job of that this year" (Participant 22, Interview).

Within the code Help, participants' comments were fairly evenly split between things that helped them, versus things they still needed help on. Pacing was a complicated topic. It could be found mentioned as a modeled activity, but it was also coded as Help with views both positive and negative. Though viewpoints varied widely, it is clear that pacing was an unmet need for many.

The last code, Confidence, included many comments that expressed an increased confidence to teach AP Biology as a result of the APSI. For instance, Kerry said, "Going to the summer institute saved me I think in teaching this class" (Participant 37, Interview). Cody also found it useful and said, "I think it was really useful and I think that for somebody that was going to go in and teach AP Bio it was a big help" (Participant 4, Interview). Finally, Theresa expressed her confidence with, "I felt way more confident starting this year" (Participant 28, Interview).

Table 27

APSI Topics Found Within the Five Self-Efficacy Codes

Code	Topic	Number of Statements	
		Positive	Negative
Mastery	Inquiry Lab Using Statistics Presenting	18	0
Modeling	Questioning Pacing Free Response Activity/Active Learning Videos	9	3
Confidence from Others	School Support Peer Collaboration Student Feedback	3	2
Help	Pacing/Planning Lab Prep Content Syllabus	11	10
Confidence	Student-Centered Overwhelmed/Challenging Imposter Syndrome Preparing Students Impact/Helpful	26	14

Note. The first three codes are from Bandura's theory of self-efficacy (1977). The last two I derived from segments that were clearly about self-efficacy, but which could not be coded based on Bandura's theory due to insufficient detail in the statement.

It is worth noting that my results showed a theoretical alignment with Bandura's (1977) theory of self-efficacy. Bandura felt mastery was the most important experience for increasing self-efficacy, followed by modeling, then by confidence derived from another. One hundred percent of the segments that described mastery experiences from the APSI, were positive statements reflecting increased self-efficacy. Bandura considered modeling experiences importance but “a less dependable source of information about one’s capabilities than is direct evidence of personal accomplishment” (Bandura, 1977, p. 197). I coded 75% of the comment segments regarding experiences modeled during the institute as positive. While lower than the 100% positive coding seen with mastery, it is still a large percentage as theory predicts. Bandura found “social persuasion” (Bandura, 1977, p. 197), which I coded Confidence from Others, to be a contributor to self-efficacy, but the least significant of the three sources discussed here. My results, again, aligned with this theory; 60% of the segments regarding confidence from an outside source were coded as having a positive affect on self-efficacy. While this percentage is the lowest of the three, it is still a large percentage.

Intention. Almost all of the intentions reported by participants related to future planned behaviors with students in the classroom, were based on reformed ideas (90%), and related to activities experienced during the APSI. I examined 19 segments which I coded as Intention; 17 of these reflected the reformed perspective. The reformed intentions fell into two categories, the intention to include more inquiry, and the intention to include specific active learning activities modeled or mastered at the APSI. The most frequent comment mentioned the intention to increase the level of inquiry offered to students in the future. Angie declared her future goal when she said, “I’ve been trying to add inquiry wherever I can, but down the line, it will be my focus” (Participant 35, Interview). The only distinctly traditional perspective seen in an intention was a participant’s plan to complete an electrophoresis lab as an online simulation rather than perform the inquiry lab activity introduced at the APSI. The electrophoresis lab is expensive and technically more difficult than most of the thirteen AP labs, which may explain the substitution. Interview participants expressed the intention to perform virtually every activity completed and coded as a Behavior in other segments from other interviews.

Behavior. Classroom behaviors reported after the APSI were predominately (93%) reformed. Interview data overwhelmingly indicated that reformed behaviors and strategies stressed in the APSI had indeed made it into participants' classrooms. I isolated 59 comment segments related to classroom behaviors from the interview transcripts, and 55 of these were consistent with reformed beliefs in science teaching. I divided these segment into four categories based on the BARSTL subscales to examine what aspects of reforms were represented in these transferred behaviors. When a participant mentioned using an activity or strategy used with students, I considered it a classroom behavior. Out of 59 statements coded as Behavior, I categorized 30 as Lesson Design and Implementation (LDI), 14 as Characteristics of Teachers and the Learning Environment (CLE), 14 as Nature of Science (NOS), and one as How People Learn (HPL). What were these behaviors?

Behavior comments I coded within the subscale Lesson Design and Implementation (LDI)*,* included comments about both general activities (such as inquiry) and specific activities. Sampson and colleagues (2013) defined the dimensions of this subscale, in terms of reform, as "student-directed learning" and a heavy reliance "on student-directed investigations, manipulative materials, and primary sources of data" (Sampson, et al., 2013, p. 6). I will first give examples of the general influence of the

APSI on the classroom Behaviors, and then I will follow with some specific examples provided by the participants.

Kerry said, “I use a lot of the activities that we talked about” (Participant 37, Interview). Leah mentioned she used “pretty much all” (Participant 2, Interview) of the labs from the APSI. The lab schedule was ambitious to give participants as many mastery experiences as possible from the labs in *AP Biology Investigative Labs: An Inquiry-Based Approach* (The College Board, 2012), but this full schedule caused some stress as we saw Sonja express, “It was a little bit confusing at the time, trying to get all of those labs done in one week, but as I’ve been trying to do it [labs] it has really helped me a lot” (Participant 22, Interview).

Inquiry labs were a major APSI activity with a reform focus. Kerry provided evidence of this behavior in her classroom when she said, “We have started with a little supported inquiry” (Participant 37, Interview). Furthermore, Leah also provided a window into the use of inquiry lessons in her classroom:

> I usually start out with a lab and then allow the students to go a little bit deeper and design their own experiment. So they have started realizing, oh we can ask more questions than those Ms._ gave us originally. They are so used to experiments have to be done a specific way, we have to get the same results, and I’m breaking them of that habit. (Participant 2, Interview)

The first two inquiry lab activities I presented at the APSI were on the topic of photosynthesis and were often referred to as the Leaf Disc Lab and the Algal Bead Lab. Angie described her use of inquiry in this specific lab, “For the leaf disc lab, I had the students do the first portion then they did the more inquiry second portion" (Participant 35, Interview). She continued by describing her follow-up activities that were modeled on those from the APSI, "They shared out, they made big posters and then we had a Q and A session after they presented them, and that actually went really well" (Participant 35, Interview). James, Elizabeth, and Leah mentioned using one of the photosynthesis labs from the APSI in the classroom as well.

Leah pointed out her use of the inquiry lab on pill bug behavior. Sonja mentioned this lab as well: "The pill bug lab, I did that, I went by a lot of what you did on that" (Participant 22, Interview). Theresa mentioned the same lab in terms of two strategies we practiced: "We did our pill bug lab posters and then we had like presentations" (Participant 28, Interview).

Participants mentioned the value of the mastery experience in the lab when it came time to do the lab with students. Julie said, "Right now we are doing [the] water potential series [osmosis and diffusion lab] and it was nice to go through" (Participant 3, Interview).

Regarding lack of equipment, which can easily derail a lab program, Elizabeth found that information from the APSI was helpful in overcoming this obstacle.

> I'm on a super limited budget. We just got done with the DNA fingerprinting, the restriction enzymes, so we had to build our own electrophoresis rig. And I remember you saying, well if you can't afford to buy one, build one, it's online. So we figured out how to build an electrophoresis rig. I actually had my research

class figure out how to do it. We ran a couple trials until it worked. (Participant 30, Interview)

Lab activities were not the only behaviors I coded as LDI. Other student directed activities mentioned by participants that could be traced to the APSI included active learning activities involving manipulative materials. One participant reported using a cell membrane/cell-signaling lesson that I modeled in the APSI:

> I was able to do that, almost, not exactly, using a picture [for the bilayer background], and using [molecule pieces] as they're listening to me talk, they are manipulating [the pieces] themselves and using their neighbor [as a helper] to manipulate their pieces on the cell membrane, I was also able to do that. (Participant 33, Interview. Bracketed material added for clarity)

I coded two comments Traditional and one Mixed in the LDI subscale, all referring to direct teaching in the form of note giving. Alternatives to "sage on the stage" information presentation remains a concern for some teachers even after the APSI with a student-centered approach. Julie's comment reflected a resignation on her part rather than an eager embrace of a formal lecture approach; "I tried the notes outside of class and that didn't work, so now I'm giving more notes inside of class, taking away from other things" (Participant 3, Interview). Another approach, coded as Mixed, is seen in Sonja's comment, "I don't do just a ton of notes because they just zombie out on me" (Participant 22, Interview). Though the behavior is reformed, the rationale is based on avoiding a negative behavior.

The subscale Characteristics of Teachers and the Learning Environment (CLE), included dimensions for the reformed perspective such as "teachers acts as facilitator, listener, and coach" as well as a, "focus on learning together and valuing others ideas and ways of thinking" (Sampson et al., 2013, p. 6.) I found that the strategy most transferred to the classroom was the use of posters to present lab results. This strategy was featured in several APSI labs. Using posters for sharing lab results in the classroom was mentioned in six of nine interviews including Elizabeth who said, "I've used that like four times already, where we made those posters" (Participant 30, Interview). Teacher participants also reported using small group discussion, collaboration, and writing strategies. James, who mentioned a specific active learning activity involving manipulation that I coded as LDI, also spoke about the general transfer of this strategy to the classroom.

> I think you did a lesson for us, kind of showing us what you thought or what you do in your classroom, and I think it was one of our last days there, and it really gave me some insight on how you used, whether it was homework or reading or pre-existing learning to kind of guide the lesson, and I think I have been able to do that the majority of the time with my school here. (Participant 33, Interview)

I used the subscale The Nature of the Science Curriculum (NOS) for further coding behaviors using activities that integrated and applied concepts leading to a deeper conceptual understanding (Sampson, 2013). These conceptually rich active learning exercises included a Hardy Weinberg activity, Short-legged Dogs (Chi-Square), and The Electron Transport Chain Drama among others. Angie shared her thoughts on the Short-legged Dogs activity that was completed in the institute with the AP Statistics group, "We did the chi-square lab with the short-legged, long-legged dogs. Yeah, it went so well, that was the lab that the students came away understanding the best." (Participant 35, Interview) This activity integrated genetics and statistics and ended with the creation of a sampling distribution for chi-square developing deep conceptual understanding. Sonja also reported using statistics from the workshop, "I've not had that, so that was good, and the chi-square, (and) I spent a lot of time on that, and I think most of the kids understand that" (Participant 22, Interview). Working with the AP Statistics participants led to a much deeper understanding of the statistics. Theresa discussed working with this group on standard deviation, "So being able to just kind of use that math and have them come in while we had the data in front of us and practice that, it's huge. It's been really helpful. That has been definitely something that I have used." (Participant 28, Interview)

Angie also mentioned the Hardy Weinberg activity, which let students explore the Hardy Weinberg conditions in a student-directed simulation while integrating many foundational topics such as meiosis. She says, "We did that alleles game with the headbands. I did that with all of my classes and they loved it. That was such a hit." (Participant 35, Interview) Although high student interest is desirable in classroom activities, this was more than that. Theresa said, "So being able to kind of model that out [Hardy-Weinberg] and watch it happen, really helped them understand that better (Participant 28, Interview).

Sonja mentioned a behavior coded in the subscale How People Learn About Science (HPL) in her use of journaling as a tool used by her students, allowing them to write about and reflect on their learning. She ended with the observation that, “We did a lot of that [during the APSI]” (Participant 22, Interview). I added the bracketed information for clarity.

Summary

My analysis of participants’ interview yielded two important findings: (1) participants’ beliefs, intentions, and behaviors after their APSI experiences overwhelmingly indicated reformed responses; and (2) reformed teaching behaviors described as participants’ current classroom practices could often be traced back to experiences participants had in the APSI. A third finding, less important, but noteworthy in the planning of future APSI, was that participants’ expressions of traditional beliefs appeared to be nuanced, often reflecting a struggle with the belief in student-centered learning in theory versus student-centered learning in practice.

I also observed that participants’ self-efficacy was greatly enhanced. However, it was compartmentalized. I found teachers more confident in inquiry and active learning but concerned about pacing and differentiation. If the topic had been modeled or mastered in the APSI, the teacher self-efficacy was high in the descriptions of their classroom implementation, but without this experience the results were mixed. Participants made many statements showing confidence to teach the AP curriculum in the classroom. The proportion of positive comments increased along theoretical lines, 100% for a Mastery experience, 75% for Modeling, and 61% for Confidence from “others. ” This aligns with Bandura’s (1977) theory of self-efficacy which theorizes that the biggest contributor to change in self-efficacy will be mastery experiences, followed by contributions from modeled experiences, followed by experiences where confidence is gained from others.

My aim for conducting interviews was to find evidence of connections between institute events and evidence of teachers' reformed beliefs and behaviors from their explanations of their post-institute teaching in their classroom. I used directed content analysis because the coding was based on theory (Hsieh & Shannon, 2005). An analysis based on theory, therefore, allowed me to develop a deeper understanding of participants' progressions of change. The use of theory, as well, provided a framework for me to confirm and make sense of how and in what ways my participants changed their thinking to reflect reformed beliefs, attitudes, intentions, and behaviors.

I will turn now to my final research question where I looked at impediments to the transfer of reformed behaviors to the classroom. Discovering roadblocks to reform will allow me to address them.

Section III: Interference with Classroom Transfer

Research Question Five: Tensions in the Activity System *Teaching AP Biology*

How can the activity theory lens assist in understanding issues surrounding classroom transfer? Accepting the activity system view of schools as complicated systems composed of many parts, we recognize the potential for tensions that can upset the working of the system. This is certainly a possibility when teachers bring an unfamiliar student-centered pedagogy into the system after they have engaged in new summer training. Engeström (2015) called these tensions "contradictions." In this fifth and final research question, I analyzed the tensions identified by APSI participants as interfering in some way with their smooth introduction of reformed science practices into their classrooms.

I previously discussed activity theory and the identification of contradictions within an activity system in Chapter Two and I have provided a summary here. Engeström's (2015) activity system model (see Figure 1) is powerful because, "the model is actually the smallest and most simple unit that still preserves the essential unity and integral quality behind any human activity" (Engeström, 2015, p. 65). The human activity I examined was teaching AP Biology after attendance at an APSI. I named this system *Teaching AP Biology.* Understanding this system required the inclusion of the Tools, Subject, Object, Norms, Community, Division of Labor, and Outcome because they are interacting components of the system. The connections within and between these components of an activity system must flex and stretch to accommodate changes in the components, such as new Tools, until a new equilibrium is reached. DeVane and Squire (2012) viewed CHAT (Cultural Historical Activity Theory) as a tool to see, plan and map these accommodations.

> CHAT is unusual in that it is not a learning theory (per se), not an instructional theory, and certainly not an instructional-design theory. Rather, researchers employing CHAT use it as a tool for understanding learning, refining instruction and suggesting directions for instructional design. (DeVane & Squire, 2012, pp. 250-251)

DeVane and Squire (2012) recognized CHAT was a useful lens through which to view the stability of America High Schools, particularly the way schools were able to absorb changes without a total reorganization. I recognized that many individual participants and their schools made this accommodating stretch, or resolution of conflict, without problem, but I have focused my analysis on the situations where the contradictions were not yet resolved. By identifying contradictions, I also identify a direction for workshop revisions with the potential to increase the transfer of reform practices to the AP Biology classroom.

Analytic Method

To answer Question Five, I searched the qualitative data sets for participants' mention of contradictions or tensions, which I defined as any beliefs, attitudes, intentions or behaviors that interfered, or had the potential to interfere with the transfer of reformed student-centered science teaching and learning into participants' classrooms. Using traditional constant comparison content analysis, I iteratively identified 369 comment segments in the qualitative data sets reflecting potential tensions affecting the success of the activity system, *Teaching AP Biology.* Open coding of the segments yielded 52 initial codes, which I reduced to 42 after several iterations of analysis. I assigned the final codes to one of five categories: (1) Students, (2) Teachers, (3) Teaching, (4) Concerns with Student-Centered Learning, and (5) Logistics. Examination of the data within these categories led to my choice of the theme: *Student-centered Versus Teacher-centered Classroom*.

I then used the activity theory lens to assign each of the data segments describing a tension or conflict to one of the seven general activity system components identified by Engeström (2015): (1) Subject, (2) Tools, (3) Object, (4) Norms, (5) Community, (6) Division of Labor, and (7) Outcome. Where conflicts involved more than one component the segment was assigned to a pair of components. My purpose was to use Engeström's heuristics to assign the tensions or conflicts to components within the activity system of *Teaching AP Biology*; that is, those beliefs, intentions or behaviors identified by participants as negatively affecting their transfer of reformed science teaching and learning behaviors into their classrooms.

Teaching AP Biology: An Activity System

The ultimate purpose of the APSI was to facilitate teachers' implementation of AP Biology at their schools. As the facilitator of the APSI, I wanted to examine my participants' perceptions of real and projected issues surrounding their classroom implementations. I labeled this activity system, *Teaching AP Biology,* and identified the theme of *Student-centered Versus Teacher-centered Classroom* as one that enveloped the contradictions affecting teacher participants' abilities to transfer reformed science teaching and learning behaviors experienced in the APSI to their own classrooms. I examined the contradictions within the activity systems at four levels: primary, secondary, tertiary and quaternary as described by Engeström (2015). He described a primary contradiction as one existing within one of the seven components, and a secondary contradiction as one existing between components. At the tertiary level the contradictions are between a current activity system and a potential, culturally more advanced, form of the activity system. Finally, the examination of quaternary contradictions involved looking at interacting neighboring activity systems. In this final case these systems would be required to effect science reform more fully.

In the *Teaching AP Biology* activity system, I identified Subjects as the participants involved in the APSI, but now from their points of views as teachers of AP Biology rather than workshop participants. The Object of *Teaching AP Biology* was the teaching of AP Biology for conceptual understanding. I examined the transfer of Subjects' understanding into actual reformed classroom practice in this activity system, (see Figure 16). Figure 16 illustrates the primary contradictions of the activity system *Teaching AP Biology* placed within Engeström's model of an activity system (Engeström, 2015). This is the activity system I examined for contradictions that affected the implementation of workshop activities. *Teaching AP Biology* is a closely related but separate system from *Preparing to Teach AP Biology*. Next, I will describe this original system (*Preparing to Teach AP Biology*), which maps the work of the APSI.

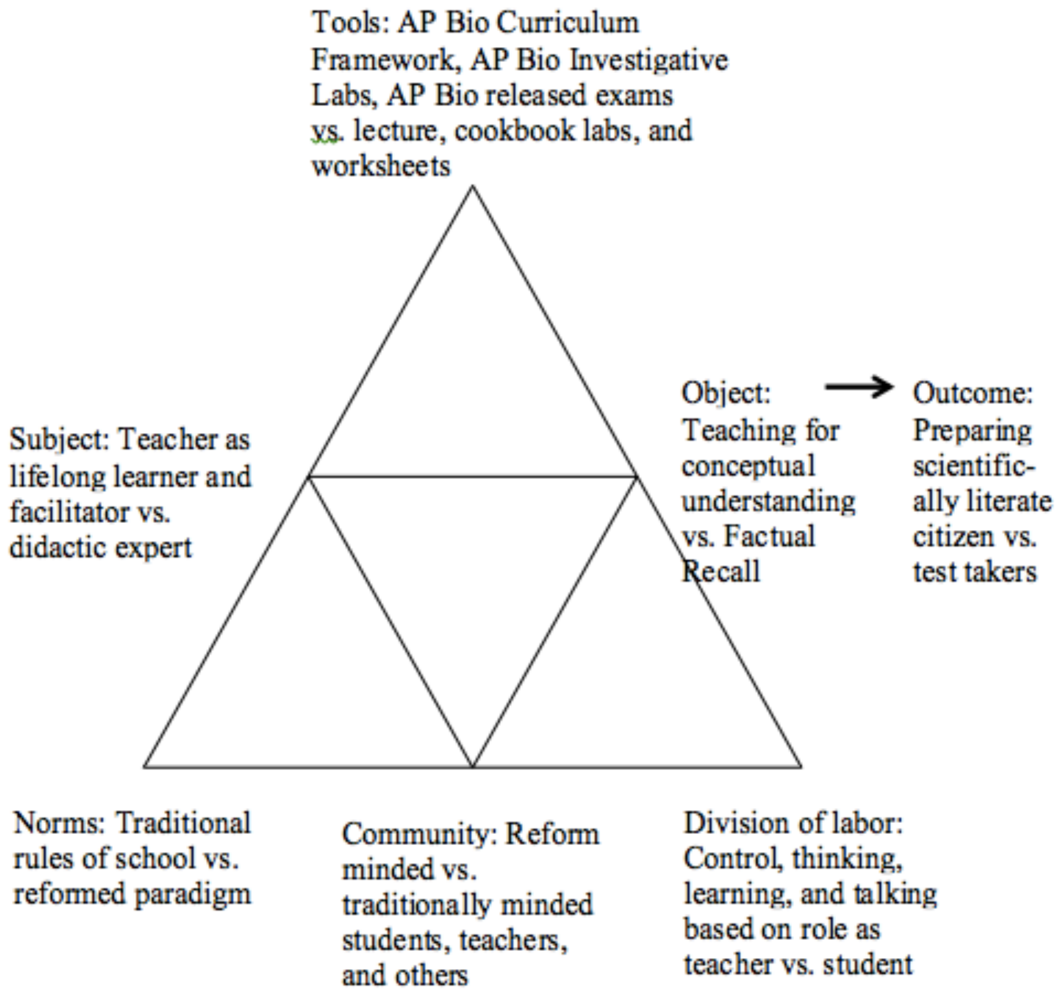

Figure 16. Sources of primary contradictions between student-centered and teacher-centered classrooms within the central activity system of *Teaching AP Biology*.

Connection to the Original, APSI Activity Systems. I viewed the APSI as the activity system, *Preparing to Teach AP Biology*, with two points of view as explained in Chapter Two (see Figure 4). One view was from the perspective of the APSI participant as Subject with the Object (goal) to be prepared to teach a student-centered, conceptually based AP Biology class. Another view was from my perspective as that of the facilitator. My Object in this system was to change participants' beliefs about science reforms while preparing them to teach AP Biology. My reasoning was that a change in beliefs would bring about the desired Outcome: to change teachers' behaviors in the classroom leading to greater student success.

The Object of the initial, *Preparing to Teach AP Biology* activity system, was that the Subjects (participants) would leave the APSI with a conceptual understanding of student-centered learning consistent with science reforms and be able to use them in the classroom. To reach this goal, I focused on important student-centered strategies such as collaboration among participants, the inquiry laboratory, active learning exercises, and formative assessment with the expectation that these strategies would be transferred to the classroom. Tools in *Preparing to Teach AP Biology* included the curriculum I used for the APSI. This curriculum consisted of personally developed material, curricular materials from the College Board, and all of the materials used by me during the delivery of the APSI. I expected many of these Tools from the APSI would be transferred to participants' own classrooms during the ensuing school year. As the facilitator of the workshop, I established Norms including schedules for activities, for discussions, for groupings of individuals for activities within each day's events, and for the Subjects' written reflections about the day's activities. Norms established for the APSI appropriate for high school classroom use, I projected, would also be transferred as Subject's classroom practices. Subjects within the APSI formed a Community of learners as they learned with and from each other and from me. I modeled the Community so that Subjects would have first-hand experiences in student-centered learning, this enabling transfer to their own classrooms. My modeling of Division of Labor in the APSI, which included the division of individual and group responsibilities for successfully achieving the Object of the APSI, I projected would also result in successful classroom transfer to the *Teaching AP Biology* activity system.

***Teaching AP Biology* Activity System**

This first activity system, *Preparing to Teach AP Biology*, with its two points of view interacted with the second activity system *Teaching AP Biology* that was identified during analysis. I used this second activity system, teachers engaged in teaching AP Biology, to frame my answer to Question Five, involving transfer to the classroom. I will analyze the data in terms of four levels of contradictions as described by Engeström (2015).

Contradictions within components: Primary contradictions. Contradictions at the primary level are those that occurred within one of these seven components identified by Engeström (2015) within the general model of an activity system. These components included Subject Object, Tools, Norms, Community, Division of Labor, and Outcome.

Subject. As Subjects in this activity system (*Teaching AP Biology)*, participants searched for their place in the reformed paradigm of teachers as lifelong learners and facilitators. This meant dealing with conflicts between this reformed notion of teachers with the traditional teachers' belief that teachers are didactic experts. Didactic expert implies a confidence stemming from a handy, scripted reply; in contrast, the lifelong learner may have to deal with situations requiring "thinking on your toes" (Participant 16, Day Two Reflections). The conflict is evident in this statement, "What if I get nervous and I don't feel confident in being able to raise that level of inquiry and just default to what's an easy teaching thing?" (Participant 30, Interview). This participant found that the questions came naturally when teaching, but others had more difficulty in spite of modeling during the APSI. One participant stated in an interview, "I thought your inquiry was good, and I always liked the way you would say, what if this, or what if that, but I've not done just a great job of that this year" (Participant 22, Interview). One teacher mentioned the need to present herself as able to do the job, with a chuckle that seemed to hint at imposter syndrome insecurity, a term coined by Clance and Imes (1978) to characterize feelings of individual self-doubt regarding intelligence. The number of participants who were concerned that their biology background was weak surprised me. Almost all of the participants had a degree in biology. This reflects a conflict between a perceived need to "know it all" and comfort with becoming a lifelong learner.

Tools. The change in the AP Biology program was largely felt through a change in Tools. The AP Biology test itself had changed, as had the guiding document (curriculum framework) and the program lab book. The new labs were inquiry labs, the learning approach was student-centered, and the AP Biology test contained questions that required conceptual understanding. This stood in sharp contrast to Tools used in more traditional teaching such as cookbook labs, “sage on the stage” lectures, and independent worksheets. Some participants felt a strong need to provide notes and lecture, an old Tool, unless given an active learning twist. Ironically, I found participants torn between enjoying the vast number of resources that were available and dreading the time and effort required finding just the right one.

Norms. The Norms within this activity system referred those Norms found in high schools, which were numerous and both logical and illogical. I found conflicts within the activity system component Norms at the levels of the teacher, student, the school, and beyond.

School-level Norms and beyond. These Norms included society’s common view of master teachers as unquestionable experts and skilled lecturers, and the existence of orderly classrooms as preferable to those showing surface chaos. These Norms are in conflict with the viewpoint of teacher as learner and facilitator rather than a didactic expert. They also conflict with reformed views of student-centered teaching in that these Norms fail to recognize that active learning is not a silent, solitary activity.

In some cases, school-level Norms were the sources of tensions that reduced the transfer of reformed strategies from the APSI to the classroom. These Norms included those under which teachers work but over which they have no control. Schools, not teachers, control class time, but the provided time was mentioned by many participants as inadequate for the task of teaching AP Biology. My participants reported both inadequate time and unpredictable schedules as interfering with their planned teaching activities. Time for inquiry lab experiences suffered the most when teachers had short class periods, particularly 45 minutes. Schools also created and assigned teaching schedules that made the demands of planning and implementing a complex AP class stressful. Participants with multiple class preparations expressed frustration with their efforts to deliver AP Biology. In addition, schools established Norms controlling student placements, which caused problems for teachers when students were inappropriately placed. One placement problem was student initiated but school-policy driven, referring to that Norm that students were awarded more grade points for AP classes. The participant felt that this drove the enrollment of students that were unprepared or unmotivated. One of my participants was concerned about what summer homework to assign. His concern was not because he felt summer homework was unimportance in meeting his curricular needs, but because the school had required it.

Student and teacher level Norms. Norms at the student and teacher level held contradictions as well. Some participants felt students should have a certain level of prerequisite knowledge and skill; when it was lacking, they felt obligated to teach the basics. They resented the effect of remediation on their overall agenda. Though a Norm of teaching a course is that teachers possess a mastery of the material, a few teachers mentioned examples of course material they did not understand. Some participants found a conflict between the difficulty of their course, grade-wise, and student expectations that they were “A” students. This caused some students to drop rather than face the challenge, though one participant who enjoyed success with student-centered learning has found lowering the stakes and stress is a solution.

Community. The complex Community in the complex *Teaching AP Biology* activity system contained teachers, students, administrator, and parents within the school setting. Tensions existed here that affected the realization of the Object of *Teaching AP Biology*; teaching for conceptual understanding of biology and therefore the Outcome; preparing scientifically literate citizens. In some cases, traditionally-minded teachers within the participants' school Communities projected negative views of reform. Some students, as well, were strongly opposed to reformed activities. Other contradictions involved variability in students and workloads. Some participants felt a disparity in the workload of AP Biology with other teachers residing within the Community. Furthermore, teachers mentioned that students in the Community do not all have the same needs and abilities, thus creating problems for participants as they searched ways to handle the variations.

Division of Labor. Examining the Division of Labor within this activity system required me to consider the jostle for control within an emerging reformed science classroom. It is difficult to isolate conflict here as simply within this component. While teachers fear the loss of control in the classroom with reformed practices, they must yield control to students to some degree to realize the gains of reformed science teaching. Additional contradictions centered on beliefs about who does the talking, the thinking and the learning within the science classroom.

Contradictions across components: Secondary contradictions. In this analysis of secondary contradictions, I examined the qualitative data sets for examples of participants' perceptions of difficulties in implementing reformed practices in their classrooms that indicated conflicts between two components. Results led to my identification of eight contradictions between various components. The tensions between the components of the activity system are summarized in Table 28.

Subject-Norms tensions. Teacher participants' tensions between Subject and Norms revolved around taking on the role of lifelong learner and facilitator and fear of failing in this role. Teachers were worried about not doing the right thing for their students by teaching in a student-centered approach. Some were uncomfortable with this teaching style and credit their concern with their newness to the profession. Assumption of the role of a didactic expert seemed like a way to avoid some difficulty seen in the reformed role. When asked about concerns regarding teaching the material, one participant verbalized this vulnerability: "The fact that you can make so many mistakes, as a teacher you are always afraid of making mistakes or getting that one question from a student that you can't answer" (Participant 1, Day 3). The tension between this and the traditional Norm of the teacher as an unquestionable expert is clear. The traditional paradigm can be so strong in individual schools that teachers must defend themselves. One teacher, in response to student pushback, felt the need to support the use of student-centered learning by providing the principal with a related article from a national education journal.

Table 28

Secondary Contradictions Between Components Within The Activity System Teaching AP Biology

Conflict Components	Explanation	Example Quote
Subject and Norms	Being a student-centered teacher means going against the Norms of teacher as expert and teacher as information giver. This may be uncomfortable.	“The fact that you can make so many mistakes, as a teacher you are always afraid of making mistakes or getting that one question from a student that you can’t answer” (Participant 1, Day 3).
Subject and Community	Student, parents, other teachers, and administrators may not support a decision to be a student-centered teacher. This may lead to lack of confidence.	”One of them said I was a lazy teacher… I’m working so hard and the guy next door is showing movies all the time. I think one of the problems is when you make it look easy, it’s like a duck, you make it look easy, but flippers are going under the water like crazy” (Participant 28, Interview).
Subject and Division of Labor	Students may not be happy about a new Division of Labor. There may be resistance to calls for students to take ownership of their learning. This resistance can feel personal.	“A lot of times what I learned this summer has been frustrating because I can’t seem to get the kids to want to think” (Participant 22, Interview).
Tools and Subject	Teachers need to find new appropriate Tools and perfect the use of these Tools. The learning curve here may not be comfortable. Discomfort may lead to abandoning the new Tools and returning to the old.	”I was just afraid, what if I get nervous and I don’t feel confident in being able to raise that level of inquiry and just default to what’s an easy teaching thing?” (Participant 30, Interview).

Table 28 (continued)

Conflict Components	Explanation	Example Quote
Tools and Norms	New Tools such as inquiry labs, active learning, and presentations take more time. This may be a source of tension with scheduling Norms. Students may not like the new Tools when they conflict with existing norms.	"No, just give me a PowerPoint, that's how we learn best, please don't make me stand up, don't make me do this" (Participant 35, Interview, Paraphrasing students).
Tools and Division of Labor	The new Tools require a shift in responsibility for learning to the students. The tension here includes conflict over giving up the old Tools such as didactic lecture and cookbook labs and replacing them with active learning and inquiry.	"I thought I'll assign these things and they will understand them and we will be able to discuss them in class " (Participant 3, Interview). It is, "hard when students don't hold up their end of a contract," (Participant 30).
Division of Labor and Norms	The new Division of Labor, where teachers facilitate and students actively participate in their learning, conflicts with the traditional Norm of passive students and teachers as knowledge provider. Teachers must yield control and students must accept new responsibility.	"Even if they don't know it I think that active learning is far more helpful" (Participant 35, Interview). " 'We're not thinking, we are not learning anything', yeah, you are, you are learning." (Participant 28, Interview)
Community and Norms	Members within the Community do not share the same view on the need to change the Norms from teacher-centered to student-centered learning.	"We have other teachers, maybe they have been teaching for a while, and it is very strictly like lecture, take my notes, exactly like I have them, memorize the organization of how this is, and when you take a test, these are the things you need to know." (Participant 30, Interview)
Community and Outcome	All community members did not hold the same point of view on the outcome of the *Teaching AP Biology* activity system. Where there is no common goal, there is no path to achieve it.	"Do we want equity, do we want them to be able to access this course even though we know they are not going to perform, or do we want to limit the kids that enroll because we need to make our numbers better?" (Participant 37, Interview. Recalling a school conversation).

Subject-Community tensions. The tensions between the components Subject and Community are dependent on the specific Community considered. Major tensions appeared to exist between reform-minded and traditional teachers at particular schools. This situation could occur when a teacher returns from an institute, ready to implement reformed strategies, but finds the school Community unsupportive. One participant, who was very positive about student-centered teaching, described the situation this way:

> We have other teachers, maybe they have been teaching for a while, and it is very strictly like lecture, take my notes, exactly like I have them, memorize the organization of how this is, and when you take a test, these are the things you need to know. It's not... it's a lot of information and a lot of note-taking, because I hear that stress level on students, but it's not a lot of critical thinking. (Participant 30, Interview)

Another participant began teaching AP Biology with a veteran AP Biology teacher who retained many traditional activities inconsistent with the goals of the new test. The participant was frustrated by her lack of input into planning the course, but this participant held out hope that the veteran teacher would learn new things brought back from the institute. This environment was unlikely to provide the type of belief support (subjective norm) that can positively factor into the equation in the theory of planned behavior making reformed behaviors less likely.

A much more personal level of tension arose when there were conflicts between the teacher and their own classrooms of students. A participant described her feelings after a student complaint about student-centered strategies like this:

> One of them said I was a lazy teacher… I'm working so hard and the guy next door is showing movies all the time. I think one of the problems is when you make it look easy, it's like a duck, you make it look easy, but flippers are going under the water like crazy. (Participant 28, Interview)

This situation in student-centered learning occurred the year before the APSI. This participant explained the institute had increased her confidence and helped her deal with this tension to prevent a reoccurrence. Another tension found here was the desire to give the best to students and the teacher's insecurity regarding the effectiveness of the student-centered learning, versus teacher-centered approaches to teaching.

Subject-Division of Labor tension. One element of the Division of Labor was in regard to ownership of *the thinking*. A tension can exist between the Subject and Division of Labor when a participant feels frustrated by the APSI information. One participant explained that she felt unable to get students to think: "A lot of times what I learned this summer has been frustrating because I can't seem to get the kids to want to think" (Participant 22, Interview). If the Division of Labor is such that the student is in charge of the thinking, what role does the teacher play in making that happen?

Tools-Subject tensions. The participants valued the statistics newly required in the AP Curriculum Framework (The College Board, 2011), as a useful Tool, but many were worried about their math backgrounds and that of their students. The complexity of the curriculum framework left some teachers unsure about planning and pacing and how to pull it all together. One participant needed Tools to support her English language learners and several desired Tools to help with reading comprehension of the college level text.

Participants expressed concern about teaching the inquiry lab before the APSI began. At the end of day one this tension was still evident with concerns over skills needed to implement inquiry, but this tension was largely resolved by participation in the APSI because it offered mastery experiences in the AP labs. School year interviews showed participants were very successful at teaching the inquiry lab. One participant, writing about an inquiry electrophoresis lab noted, "It's one thing to read about it, but entirely another to perform it" (Participant 29, Day Two Reflections). For some participants the conflict they felt with the new Tools remained. Participants described inquiry as hard, especially when student inquiry experience was limited, or when the lab didn't work as they expected and reported skipping particular labs if they lacked supplies due to budget or organization.

Tools-Norms tensions. The Tools in this activity system were defined to include inquiry labs and activities, but a conflict was apparent between the suggested Tools and existing Norms regarding time. It would be a rare science teacher indeed who was scheduled with extra preparation time to prepare materials for inquiry labs or other student-centered learning experiences. For some, the time issue was even more acute, such as a teacher assigned to three different course preparations. Time was also considered a problem in completing the intensive inquiry labs, sometimes within class periods as short as 45 minutes. This conflict caused one teacher to reduce expectations for the inquiry lab experience. She said, basically, that guided inquiry, rather than open inquiry, would have to do.

An additional Tool, presentation to peers, was very popular with teacher participants, but became apparent as a tension in the classroom. If the Norm of traditional school is one of “sage on the stage” teacher, the role of student as a presenter can be an uncomfortable shift. One participant described this by paraphrasing the words of the students, “No, just give me a PowerPoint, that’s how we learn best, please don’t make me stand up, don’t make me do this” (Participant 35, Interview).

Tools-Division of Labor tensions. Student-centered learning involves changes in the Division of Labor component including who is in control of the talking, thinking, and learning. Teacher participants were concerned about this control shift, and one noted that in order to maximize their use of active learning it would be important to learn how to maintain control. Yielding yet maintaining control sounds contradictory. In my experience, yielding control over some of the intellectual decisions and thinking work of the classroom while maintaining a climate of mutual respect, makes classroom management concerns (control to some) minor. I found it noteworthy that the participant felt classroom control was a prerequisite to active learning.

Yielding control in the student-centered classroom is not always easy. Teachers and students have an implied contract about what preparation is required for lessons. It is, “hard when students don’t hold up their end of a contract,” according to participant 30, particularly when students come unprepared and the teacher put all their “eggs in the inquiry basket” (Participant 30, Interview). Yielding the classroom “thinking” implies that someone is willing to take it over, an assumption that proved problematic for some teachers.

Division of Labor-Norms tensions. Revising the Division of Labor in the student-centered classroom had implications that affected the Norms. Instead of the notion that the teacher is an all-knowing expert, participants must accept a new paradigm where the belief exists that discussion between students can result in more lasting learning. Participants realized that time on taking notes, a traditional classroom Norm at this level, takes time away from students doing the talking, thinking and learning. In the new paradigm, students take on a more active role, which is in contrast to a traditional passive student role.

Community-Norms tensions. Teachers also recognized tensions between the school Community's ideas of the Norms of school, and teachers' desires to change these Norms. A participant described student-centered learning in a thought provoking way by saying it was like "medicine they need to take" (Participant 28, Interview). Her statement seemed to imply a less than hardy acceptance of student-centered learning, though this participant shared many positive statements about its value. The contradiction within the Community (e.g. teacher and parent, or teacher and student) over the "correct" Norms could be extreme. In one instance, for example, an administrator even felt the need to warn a teacher about student resistance to prepare her for parent pushback. Views from these Community members affected the subjective norm for teachers and influenced what teachers thought they should be doing. Negative views here were likely to reduce the use of student-centered reformed strategies. (Note:

This was discussed in Question Four.) In a positive note, one participant reported that administrators look for student-centered learning in classroom observations, providing reassurance that different reformed Norms exists at some schools.

Outcome-Community tensions. Community members did not necessarily hold the same view of the object in the *Teaching AP Biology* activity system. A participant recalled a conversation between the teachers and administrators at her school regarding the outcome: "Do we want equity, do we want them to be able to access this course even though we know they are not going to perform, or do we want to limit the kids that enroll because we need to make our numbers better?" (Participant 37, Interview) Where there is no common goal, there is no path to achieve it.

Tertiary considerations. The third level of contradiction occurs at the intersection between the central activity system, in our case *Teaching AP Biology*, and another more advanced system that can inform progress in the central activity system. I called this potential system *Student-Centered Teaching of AP Biology* and I will describe my vision of a system where all the contradictions (tensions) formerly identified by the participants in this study have been eliminated. In this system, teachers see themselves as facilitators and learners whose role in the classroom is to nurture and guide student-centered learning. These teachers are comfortable directing and scaffolding student inquiry to reach high levels and facilitating active learning exercises that promote critical thinking. These teachers use formative assessment to guide students and lower the stakes and stress of testing. Teachers in this ideal, more advanced system have adequate preparation time and sufficient, predictable class time. Students are placed appropriately and adequately prepared for the course through prior course experience. AP Biology would not be students' first experience with student-centered learning, rather it is found in other subjects they take, and in previous levels of biology. Students enjoy a class culture that values asking and answering questions through collaboration, and they understand and aim to fulfill their responsibility toward themselves and their peers in this regard. The Community is supportive of student-centered learning. The Object of conceptual understanding is met and the Outcome of scientifically literate students is realized. I find it extremely encouraging that one or more teachers in my datasets reported each one of these items. The ultimate goal is to see all of these behaviors in all science teachers and classrooms, as the definitive success of science reform.

Quaternary contradictions. Using *Teaching AP Biolog*y as our central activity system, I then considered the fourth level of contradiction: the contradiction between neighboring activity systems. When the College Board revised the AP Biology program and test (the revisions belonging to a neighboring system), this change of Object and Outcome for teaching AP Biology initially caused instability in the system. The Object for the course changed from factual recall to conceptual understanding of biology. This created tension in the Subject component because a traditional teaching approach was insufficient to meet the reformed course goals. So with the Object and Tools changed by the neighboring College Board system, the new *Teaching AP Biology* system was filled with tensions related to teaching through a reformed, student-centered mindset. Required by the new College Board Tools, the traditional teacher-centered approach became obsolete, no longer as successful as it had been with the old Tools.

Summary to Question Five

The lens of activity theory allows us to understand how contradictions within and between components can slow down the full adoption of reformed based, student-centered classroom strategies and behaviors by a teacher following beliefs changes at an APSI.

Norms (rules), Community, and Division of Labor are components that may require significant time to change. Changes must occur in teachers, students, parents, and administrators so that student-centered learning becomes the norm and enjoys support from supervisors and at home. Community support will help reduce the tensions within Division of Labor with revised expectations of what it means to be a science student doing science. The Norms or rules of school are slow to change. This is one area requiring serious consideration if science reforms are to be the norm in all schools, not just those with progressive leadership. Schools should examine their existing Norms that make student-centered teaching hard, including longer science classes, reduced class load, smaller science classes, and proper placement of students by preparation.

Conclusion to Chapter Four

Chapter Four detailed the results of the research questions. The findings are summarized here.

- Finding 1: Participants' goals for the institute were in alignment with my goals as institute facilitator.

- Finding 2: Participants' attendance at the APSI was associated with changes in beliefs about self-efficacy and beliefs about reform in science teaching and learning.
- Finding 3: Survey results can be triangulated with teachers' statements regarding changes in their beliefs, intentions, and behaviors relating to reformed constructs.
- Finding 4: A progression in reformed teaching beliefs is congruent with theory and can be traced to the classroom, beginning with intentions to engage in reformed science practices followed by evidence of reformed behavior.
- Finding 5: Using the lens of activity theory, we can observe a conflict between student-centered and teacher-centered learning in the activity system *Teaching AP Biology*. Changes in the AP Biology program caused fluctuations in a previously stable activity system by changing the Tools. Studies of these contradictions will inform us as we consider what changes to the APSI would help resolve these contradictions and advance science education reforms.

I discussed the needs of the participants before attending the institute in response to Question One. The participants expressed goals relating to the teaching of AP Biology, and these goals intersected with the workshop goal of preparing participants to teach a reform based course. I answered Question Two with a detailed analysis of data from two survey instruments developed to measure beliefs about reformed beliefs and self-efficacy. Surveys showed attendance at an APSI for AP Biology was associated with more reformed teaching beliefs and greater self-efficacy. My answer to Question

Three followed, with segment progressions that traced beliefs and beliefs changes to intentions and behaviors and associated them with individual instrument scores. Various constructs were tied to the survey results through the words of participants. To answer Question Four, I used a directed analysis approach to analyze participant interviews tied results to the theoretical framework grounded in two theories: (1) planned behavior and (2) self-efficacy. I applied the lens of activity theory to participants' qualitative data to answer Question Five in order to identify contradictions in teachers' activity systems as they taught AP Biology in their classrooms. The contradictions found were associated with the changes in the system that started with changes in the AP Biology program from a teacher-directed to a student-centered program. A more thorough discussion of these results, with their implications, will follow in Chapter Five.

CHAPTER V

CONCLUSIONS

It is hard to overstate the importance of reforms in science education. Current reforms, underway for decades, have begun to change the way we think about and interact with the world, but there is more work to do. The College Board has revised the AP® science courses to align with science reforms, a change that could have big impacts on science education, both directly and indirectly. The overall goal of this quality improvement project was to adapt the curriculum of the summer professional development institute for AP teachers to meet the revised changes in the AP Biology® course. With my years of experience as an institute facilitator, I had sensed for some time that changes in teaching are intimately related to changes in teachers' beliefs that student-centered, reform-based teaching is a better way to prepare students in biology. Therefore, I took this opportunity to understand more about the role of AP Biology teachers' beliefs in affecting their implementations of reformed practice in their classroom teaching.

Turning to Theory

Organizing framework. I used Desimone's *Core Conceptual Framework for Studying the Effects of Professional Development on Teachers and Students* (see Figure 2) as an overall guide to the organization of this study (Desimone, 2009). Desimone's work was the foundation supporting the structure of the theoretical framework I built for this study. My hope was that the results of an improved professional development institute, aligned with this framework would support Desimone's basis thesis: high-quality professional development results in effective teachers who show changes in behavior.

Additional theories. With my interest in teachers' beliefs in mind, I intertwined the theory of planned behavior (Ajzen, 2005), and self-efficacy theory (Bandura, 1977) to ground and inform my planning for the study. The theory of planned behavior suggested three types of beliefs as antecedents to attitudes, followed by intentions to perform a behavior: (1) behavioral beliefs, (2) normative beliefs, and (3) control beliefs. Control beliefs inform the attitude of perceived behavioral control. Perceived behavioral control, is essentially equivalent to Bandura's concept of self-efficacy. Ajzen addressed the equivalency, noting that while perceived behavioral control actually combines self-efficacy with control, an investigator may decide to treat these as one factor (Ajzen, 2002) as I did. This essential equivalency allowed me to look at Ajzen's (2005) theory of planned behavior through an additional theoretical lens very relevant to teaching: how teachers perceived their own abilities to translate the workshop experience into personal classroom teaching behavior.

Frames for analysis. I used Ajzen's (2005) and Bandura's (1977) theories as the source for codes in a directed content analysis (Hsieh & Shannon, 2005) to analyze teachers' reflections and post-institute interviews to reveal any shifts toward more reformed beliefs and more positive attitudes for the group as a whole. According to Bandura's theory of self-efficacy (Bandura, 1989), an increase in self-efficacy (perceived behavioral control) drives a positive feedback loop that continues to increase successful classroom behavior. When this increase in self-efficacy (perceived behavioral control) is added to a teacher's positive attitude toward reformed behavior, and positive sense of how others see the behavior, the teacher's intention to engage in student-centered learning and reformed teaching behavior in the classroom become more likely.

Factors controlling behaviors are additive. Ajzen (2005) outlines three causes of intentions and behaviors in the theory of planned behavior, "one personal in nature, one reflecting social influence, and a third dealing with issues of control" (Ajzen, 2005, p. 117). The relative values of these three determinants: (1) the behavior (personal), (2) the subjective norm (social), and (3) the perceived behavioral control (control) are variable and dependent on the intention, the person, and the population, but nonetheless, are additive (Ajzen, 2005). A negative subjective norm results from the perception of a lack of support from important individuals for reformed teaching behavior. This is problematic because a negative subjective norm can reduce the impact of positive behavioral attitudes and positive self-efficacy. When individuals important to a person believe a behavior is important and should be performed, and that person wants to conform to those beliefs, the behavior is more likely to happen (Ajzen & Fishbein, 1980). In this study, I defined these important "others" as fellow teachers, administrators, parents and students.

An activity theory lens. I also found activity theory (Engeström, 2015) to be particularly informative in my planning for the study. While I saw that the subjective norm was not only seen as a problem in the theory of planned behavior, but also could be a source for identifying contradictions when an activity theory lens (Engeström,

2015) was applied to the teaching of AP Biology. “There is an inherent need to resolve contradictions in activity systems and this need drives change within and among components” (DeVane & Squire, 2012, p. 249). In this study, I was especially interested in uncovering contradictions existing between student-centered and teacher-centered teaching. First-hand experiences in prior institutes had led me to understand that revisions to the AP Biology course introduced tensions into a previously stable, pre-reformed system of the “old” AP Biology. The revised AP Biology test changed the Object of the activity system, *Teaching AP Biology*, from fact acquisition to conceptual understanding. This, in turn, changed the Tools needed from verification, cookbook labs to inquiry activities. Active, student-centered learning through collaboration and inquiry became important strategies as students developed conceptual understanding. If the teacher (Subject), Tools, and Object were an isolated system, little tension would have been seen, but these components interacted with other components. Activity theory identified Norms, Communities, and Division of Labor as components of an activity system of *Teaching AP Biology*, and these components were also important in creating a system supporting AP teachers’ abilities to successfully engage their students in student-centered learning.

Reasoning from the whole. How hard is it to put in place a student-centered inquiry-learning paradigm? It depends on the school and the individuals. The theory of planned behavior (Ajzen, 1985) predicts an increase in reformed teaching behaviors when three things are positive: (1) the teachers’ reformed beliefs, (2) the teachers’ self-efficacy, and (3) the subjective norm (supportive view of the behavior from the community and teachers' desire to conform with this view), but the theory of planned behavior alone cannot provide the relative weight for each component in a specific situation. Activity theory confirmed my view that the subjective norm, evident in the contradictions between components in this study, is an important determinant of reformed teaching behavior. If a school community, defined as administrators, teachers, students, and parents, fails to support reforms in science teaching and learning, an analysis of an activity system found contradictions, or tensions that reduced the transfer of student-centered, reformed teaching strategies. The school, as an activity system, has considerable power to reinforce or extinguish these changes.

Self-efficacy theory suggests successful behaviors leads to continued used of these successful behaviors (Bandera, 1977). For example, successful use of reformed teaching behaviors should increase the use of these behaviors consistent with reform. While success generally leads to more success, community resistance can reduce self-efficacy through a negative feedback loop. When lower self-efficacy is added to lack of community support, even a strong reformed belief is unlikely to be translated into a reformed behavior in the classroom. The campus environment must be considered a critical factor in the successful integration of student-centered reforms into the classroom.

Interpretation: Changes Supported by Evidence

Participants who attended my summer APSI workshop for AP Biology demonstrated changes in beliefs, followed by behavior changes in the classroom. Several lines of evidence support this claim. First, my content analysis (Question One) of participants' statements of needs and goals indicated an alignment of participants' goals with my workshop goals. Second (Question Two), my analysis of quantitative pre-post institute survey data from two instruments, the BARSTL (Sampson et al., 2013) and the TEBS-Self (Dellinger et al., 2008) revealed statistically significant increases in participants' reformed beliefs in science teaching and learning, and increases in self-efficacy in teaching, with their engagement in the four-day summer institute. In answering Question Three, I combined the qualitative and quantitative data to trace numeric belief changes from the survey results to supporting statements made by the participants in written and verbal responses. I compiled data threads consisting of sets of statements from individual participants about active learning, inquiry labs, student-centered learning, collaboration, and confidence; and I connected these threads to the associated TEBS-Self or BARSTL score changes. These threads showed a progression in participants' statements over time that paralleled changed beliefs to anticipated intentions and, eventually to classroom behaviors. I observed a high degree of alignment, which allowed me to predict that, even without classroom data, participants' intentions were likely to become behaviors in the classroom, a finding supported by the theory of planned behavior (Ajzen, 2005). To answer Question Four, I collected evidence from post-institute interviews that aligned participant beliefs to intentions and ultimately classroom behaviors. My design of the post-institute interviews was informed by the theory of planned behavior (Ajzen, 2005), and self-efficacy theory (Bandura, 1977). The theory of self-efficacy defines sources for changes in self-efficacy. I examined three of these sources in this study: mastery, modeling, and encouraging statements offered by others. My findings supported theory, in that mastery experiences had the largest effect on self-efficacy, followed by modeling and then encouragement (Bandura, 1977).

To answer Question Five, I used an activity theory lens (Engeström, 2015) to illuminate contradictions or tensions that prevented or reduced the transfer of reformed strategies from the APSI to the classroom. These contradictions simultaneously highlighted and provided directions for solutions to problems with classroom transfer of reforms from this professional development event.

One important idea that emerged in my analysis of data to answer Questions Four and Five is that changes in beliefs alone were not be enough to move ideas about science reform into the classrooms of all teachers. In schools and communities where Norms favor traditional transmission teaching, community-wide changes in attitudes are needed. These findings were directly in line with Engeström's activity theory. If teachers did not feel supported by the school or community in their implementation of student centered science teaching, they were less likely to enact the reforms they were sent to learn.

I used the theory of planned behavior (Ajzen, 2005) to predict the behavior changes I saw associated with beliefs changes. I used activity theory (Engeström, 2015) to predict changes in participants' school *activity system* as the result of their changed behavior. Engeström (2015) viewed any particular human activity as a system with various components. Oscillations in and between components of the activity system *Teaching AP Biology* were predictable with the introduction of the revised course. If I had not used theory to guide my study, I would not have realized the importance of beliefs change to behavior change, and I would not have understood the possibility of roadblocks in the way of this behavior change. Activity theory helped me find these roadblocks.

Recommendations

In *Science for All Americans*, the authors talk about the pace of reform and how it might happen when they say about teaching the, “profession may change mostly in response to turnover” (American Association for the Advancement of Science, 1990, p. 211). It has been more than a generation since this book was written. Even if we accept the slow pace of change outlined here, 27 years seems long enough to fully realize the acceptance of science reforms. Perhaps it is time to step back and ask what else can we do.

DeVane and Squire (2012) note that, “One of the strengths of CHAT is how it enables researchers to look for *contradictions* in an activity system that will drive its evolution” (p. 248). The activity system, *Teaching AP Biology* (detailed in Chapter Four), gives us information that allows us to consider future changes to the APSI that would address contradictions participants found and increase the success of transferring reformed teaching behavior consistent with the national literature (American Association for the Advancement of Science, 1989; National Research Council, 1996).

Changes to the Workshop

Most teachers were successful using most reformed strategies, but I wanted to pay attention to the areas where teachers experienced problems as a direction for workshop improvement. My use of the activity theory lens revealed conflicts that prevented the introduction of some reformed strategies into the classroom of some teachers. Many conflicts can be solved by repeating points made during the workshop to be sure teachers hear the information when they are ready to process it, holding discussions on particular points, and providing scaffolding resources, because few of the recommendations are completely new to the workshop. Conflicts identified through activity theory are the source of recommended changes to my APSI workshops. These changes involve support in the following areas:

- More tools and examples for planning and pacing of the AP Biology course.
- Strategies for reducing teacher stress-- where to find a positive normative view.
- Strategies for reducing student resistance by reducing student stress.
- Recognizing the content in the inquiry labs and student-centered approaches.
- Finding the right starting point--the reality of where students are.
- Student and teacher responsibility issues in a student-centered classroom.

More planning and pacing. Teachers wanted more time spent on the pacing of the AP Biology course at the APSI workshop. AP teachers in the past, teaching in a transmission model, were more comfortable with this aspect of teaching the course because they were able to model their course after their own experience in college biology. As I provide additional pacing and planning support in the future, I need to be careful that this support does not eliminate the need for teachers to consolidate the course concepts into their own mental models.

Finding a positive normative view. The positive normative view (the belief that personally significant individuals view reformed teaching as desirable) was missing in action, in the school setting, for some participants. Without a positive normative belief, there was no positive subjective norm (motivation or perceived social pressure to teach in a reformed manner). Not only was the lack of a positive normative view about student-centered learning a negative factor in determining the transfer of reformed beliefs, but it also increased stress for teachers when they felt alone and insecure about their classroom progress and teaching strategies. I can point teachers to resources such as the AP Biology Facebook page, but building a stronger community between workshop participants would be helpful. It would also help to make participants aware of potential negative normative views from their school community and provide resources that can used to educate stakeholders.

Lowering student resistance by lowering stress. Student resistance is a by-product of student stress with an unfamiliar activity. Students may fear they will fail at this challenge. Formative assessment and scaffolding reduce the stress on students by reducing the stakes and providing the means for improvement. Formative assessments also help students see what they are learning and can be combined with tracking learning progress against the curricular framework. One of my workshop changes will be to more directly connect these strategies with lower student stress and lower student resistance so that participants more fully understand the interconnections between the suggested strategies.

Some participants perceived the inquiry lab as a source of student stress. Students' need for reassurance comes from their prior experience that has reinforced countless times there is *one right way*. I will show teachers how I handle a "failed lab." I always do this when there is a teachable moment in the institute, but in the future I will make sure to engineer a failure if necessary and use it to have a discussion with teachers.

Recognizing the content. The labs, student presentations, collaborative activities, and active learning lessons contain the content. I need to address the misconception that students need formal notes in addition for comprehension of the same material. Associated with the expanded scaffolding of planning and pacing I will add an activity to trace the content through the activities associated with a unit.

Finding the right starting point. Equity and access are topics that I already include in the workshop, and are important cornerstones of the AP philosophy. I think the additional conversations related to the realities of student backgrounds could be helpful in bridging the gap between satisfaction with perfect student preparedness and dissatisfaction with problematic background. Teachers need additional strategies to determine what students know and how to work from there. Some problems with student background and placement are issues controlled by school systems and cannot be changed by a workshop.

I found a need for strategies to support English Learners (EL) in the AP Biology classroom. A recent National Academies of Sciences, Engineering, and Medicine (2017) report summarized proven strategies found to help English Learners. These strategies intersect with the strategies of student-centered learning. Learning the specialized language of a course requires reading in the "language", discussing the meaning of text, working with peers, and practicing appropriate writing with scaffolds as needed. (National Academies of Sciences, Engineering, and Medicine, 2017). It would be useful to discuss and practice these approaches at the workshop, approaches that are likely to improve reading comprehension for all students.

Student and teacher responsibility. The changes in the AP Biology classroom largely revolve around new roles for teachers and students. Participants need help training students to be in charge of their thinking and learning. Getting students to do work outside of the class was particularly problematic for some participants, but providing more examples to teachers of how to connect for students the *need* for the reading or other homework, through follow-up collaborative active learning exercises in class will be helpful. In the workshop I need more support for teachers on how to handle student unpreparedness through *Plan B*. *Plan B* relies on teachers understanding that shifting responsibility to the students does not relieve them of the need to be prepared to shift gears if necessary to keep moving forward. I will address misconceptions through discussions about the teachers' role in student-centered learning. A successful student-centered teacher is engaged with students, circulating and listening. This allows a teacher to uncover student misconceptions and gauge student progress.

Other Recommendations

Changes at the level of the workshop alone will not be enough to complete the change of culture in science education and realize the power of ubiquitous reform. Conflicts exist between student-centered and teacher-centered learning. Removing these conflicts will require training and support of all stakeholders in the community of students, teachers, administrators, and parents.

Increase teacher training in earlier grades. Powerful, lifelong learning, and conceptually thinking, are among the goals of reformed science teaching. One of the reform premises in *Science for All Americans* is that “comprehensive approaches are needed” and that, “At the school district level, reform efforts should be inclusive: all grades, all subject domains, all streams” (American Association for the Advancement of Science, 1990, p. 213). For some students, student-centered, inquiry-based learning in AP Biology comes too late, making them feel as if the traditional school rules have been changed in the middle of the game. Some students have been highly successful with the status quo, and there is a resistance to change. Many participants felt the pre-requisite courses were lacking in inquiry laboratories and other student-centered activities. This lack of student experience meant inquiry labs, for instance, were new and unfamiliar, sometimes leading to student resistance toward constructivist learning. Leaving the first experience with student-centered, inquiry-based learning to the eleventh or twelfth grade does not exactly make for a smooth transition. Science instruction should be student-centered from kindergarten on. Professional development experiences that prepare teachers to implement reforms need to be more widely available to teachers at all grade levels. Universal availability and utilization of training has the potential to change the normative belief of trained teachers and their students.

Change the community mindset. A workshop for administrators to learn about student-centered active learning, including inquiry, could help change their normative beliefs regarding science reforms. This has the potential to increase the success of not only the AP science teachers, but also of other teachers in a school. Administrators at both the district and school level need an understanding about the unique needs of science classes. With administrative guidance and direction, counselors and other personnel who schedule courses would understand the need to keep class sizes reasonable and ensure adequate time for science instruction. Placement decisions should ensure that students are set up for success within the zone of proximal development.

Educate the school community regarding *how people learn* science. Community conversations about shifted responsibilities in student-centered learning would be very helpful and could take place as part of course registration events, open houses, or PTA meetings. Parents, students, and administrators need to understand that teacher preparation for student-centered learning is extensive and time consuming, though it may not be apparent in the surface view of action during a class period as the teacher serves as facilitator. Administrators need to stay cognizant of this fact as they assign teachers to numerous preparations.

Provide needed resources. We need to reconsider how time and other resources are allocated. Nothing I do in the institute can add more time to a biology class. The fact that inquiry labs take longer than traditional labs is not disputed (Herron & Herron, 1971). I remember my science courses in college always had a lengthy additional time space for lab. The logic behind this seems to have been lost in the translation of college biology to the high school system. Science classes need to be longer than classes for other subjects to allow time for adequate inquiry. Participants overwhelmingly accepted inquiry, yet teachers were conflicted over the time it took.

Although student-centered learning is not more expensive, teachers must be provided adequate funds for laboratory materials and equipment. In my experience as a consultant I have found the range of funding to be huge and the lowest funding to be unacceptably restrictive on student opportunity.

Implications of These Recommendations

Implications of This Study for the APSI

To add time on one topic means to subtract time from another. This is true in the APSI as well as the classroom. I will have to make decisions about what to leave out or combine, and accept the possible consequence of a new need, previously addressed, appearing where it did not exist before. I believe more discussion with participants about tensions they may face at their school as they introduce or continue to use student-centered learning is important.

Implications of other Recommendations

Additional funding for elementary and middle school science teacher training needed to support preparedness in AP science students would compete with other needs. In addition to training expenses, increasing the amount of student-centered inquiry experiences from kindergarten to high school would require new money for supplies and additional spaces suitable for a lab. A campaign to educate the community about science reforms and the importance of student-centered learning would require an individual to be in charge of planning and preparation, taking them away from other duties. Increasing class time and reducing class size for science classes, and limiting the number of preparations for teachers of these classes would affect the entire school, a problem not to be underestimated, but the benefits not to be underestimated either. Shifting how students are assigned to an AP science, like AP Biology, affects the placement of students in other classes.

Limitations

The primary limitation of this work is the inability to generalize these results. These results are specific to this case study, meaning this group of participants, in these APSIs, and at the time of this study. The survey results were not generated from a randomized trial but were a convenience sample of participants in the study. While I made associations between beliefs, intentions, and behaviors, there is no belief that events at the APSI were the sole cause of changes in teachers' accounts of classroom behaviors.

My position as the APSI consultant and researcher had both pros and cons. While the potential for bias existed in my analysis of the results, this was offset by my unusual knowledge and experience leading to a deep understanding of the nature of the institute, the revised AP Biology course, and recommended changes in AP Biology teaching. I did not collect data through direct observation, but behavior was reported through the eyes of the teacher participants. Information from teachers, then, was used to ascertain what behaviors from the APSI made it to the classroom.

Directions for Future Research

The addition of classroom observations would be powerful. There would be considerable value in continuing this research by connecting these changes in beliefs, intentions and behaviors to student performance. This problem would require overcoming obstacles for obtaining access to student records and permission for classroom observation. While this problem may have to wait, a comparison of the amount of student-centered learning in schools with differing characteristics with regard to the related subjective norm would be an interesting area for future study. It seems logical that schools contributing to a more favorable subjective norm about student-centered learning would have more student-centered teaching reaching the classroom.

Future work on this topic involving multiple linear regression or structural equation modeling to determine the weight and predictive power for each of the determinants in the particular situation of transfer of reforms to the AP Biology classroom from an APSI would be extremely valuable.

Concluding Remarks

Reformed science teaching provides hope for developing the skills and mindsets needed to solve some of the world's most vexing problems. This APSI was one example of a professional development event that can help move teacher beliefs further toward the reformed end of the spectrum. While professional development may be able to change beliefs about science reforms, professional development alone it will not be enough, especially for teachers in situations with a non-supportive community. We must address the complex sources and issues that reduce the transfer of reformed beliefs to the classroom for some teachers.

Science education reform is important, but that importance never meant its realization would be fast or easy. Though we have come a long way, the journey to fully reformed "science for all students" (National Research Council, 1996, p. 19) is not yet over. We must embrace forward progress, but continue to work tirelessly toward the full, complete embrace of the principles of science reform.

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APPENDIX A

AP BIOLOGY WORKSHOP CURRICULUM FOR APSI

Table A1

AP Biology Workshop Agenda and Reform Strategies Used in Delivery

Day	Topic	Reform Strategies
1	• Overview of the AP Program	
	• Intro to Inquiry and Active Learning, Working with Temperature Dots	A, I
	• Photosynthesis Lab- Leaf Disc, Electron Transport Chain Drama	A, I
	• Descriptive Statistics –Heartbeat Lab (with AP Statistic)	A
	• AP Biology Curriculum Framework	A
	• Reflections	A
	• Photosynthesis Lab- Algal Beads; Poster Presentations	A, I
2	• AP Biology Equity and Access	A
	• Planning and Pacing the Course	A
	• Restriction Enzymes Inquiry Lab (Electrophoresis)	A, I
	• Bacterial Transformation Lab	A
	• Debrief Photosynthesis lab (Algal Beads) Poster Presentation	A
	• Reflections	A
	• Transpiration Inquiry Lab (Whole Leaf Method))/ Stomata Prints	A, I
3	• Sample Active Learning Lesson on Cell Communication/Macromolecules	A
	• Yeast Lab (Cell Communication)	A
	• AP Biology Syllabus & Audit	A

	• Enzymes Inquiry Lab (with AP Statistics)-Poster Presentation as Gallery walk	A, I
	• Short-Legged Dogs (Chi-Square-With AP Statistics)	A
	• Reflections	A
	• Transformation/ Electrophoresis Wrap-up	A
4	• Behavior Lab -Poster-Present	A, I
	• Finish Transpiration	A
	• Descriptive Statistics	A
	• The AP Biology Exam/ Practicing Essay Marking	A
	• Diffusion and Osmosis Inquiry Lab/Water Potential	A, I
	• BLAST	A, I
	• Hardy Weinberg Activity, Spreadsheet, Problems	A, I
	• Reflections	A
	• Discussion on Remaining Labs	A
	• Synthesis and Sharing	A

Note. The symbol "A" refers to this definition: "Active Learning is anything course-related that all students in a class are called upon to do than than simply watching, listening and taking notes." Definition from "Active learning: An introduction," by R. Felder and R. Brent, 2009, *ASQ Higher Education Brief, 2*(4), p. 2.; The symbol "I" refers to this definition: "Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations." Definition from *National Science Education Standards* by the National Research Council, 1996, p. 23. Published by National Academies Press.

APPENDIX B

DEMOGRAPHIC QUESTIONS

Enter the last 4 digits of your phone number.

Enter your age.

How long have you been working in K-12 education (in years)?

What subjects did you teach last year?

Have you taught AP Biology before? Is so for how long?

What subjects do you anticipate teaching next year?

My school is (urban, suburban, rural).

My school is (public, public charter, private).

How many college science courses have you taken?

What degrees do you hold? (Please provide major).

What is your gender?

Additional question at end of Pre-Institute Goggle form:

Please tell me about your goals for our APSI. Are there any particular topics you want to see covered in the workshop? Information here helps me personalize this week to meet your needs.

APPENDIX C

DAILY REFLECTIONS PROMPTS

Following each question, I have added the day(s) of the week in parentheses that the question was asked of participants.

Institute Daily Reflections

Questions will be selected from the following each day of the institute. Please answer the selected questions. Use your 4-digit code (last 4 digits of your phone number) to identify your answers, either in the Google Form or on paper as requested.

1. What concerns do you have about the content in today's lessons? (Wed)
2. What concerns do you have about the process involved in teaching today's lessons? (Wed)
3. What are you looking forward to using from today's lessons? (Mon)
4. What were your "ah ha" moments from today? (Tue, Wed)
5. The most difficult part of the lessons today was ... (Wed)
6. The easiest part of the lessons today was... (Wed)
7. One thing I would change about the lessons today is... (Mon, Tue, Wed)
8. One thing I learned in the lessons today that I will remember for a long time is ... (Tue)
9. My thoughts on math-science integrated lessons... (Mon, Tue)
10. My thoughts on inquiry lessons...(Mon)
11. My thoughts on active learning... (Tue)

APPENDIX D

INTERVIEW QUESTIONING ROUTE

Phase III Interview Questions: These are the semi-structured interview questions used for interviews with a subset of institute participants. These interviews may be conducted from October, 2016 to May, 2017.

Intro: Tell me about your educational and teaching background.

Intro: Tell me about your teaching schedule.

Transition: How did you get assigned to AP Biology?

Key: How is your summer institute experience impacting your teaching?

Key: What do you wish you had in the APSI that was missing?

Key: What are your biggest sources of concern in teaching your course?

Key: How do these concerns compare to those you had entering the program?

Key: What kind of help do you need now?

Closing: Is there anything you would like to share with me that I did not ask about?

APPENDIX E

OVERVIEW OF CODING SCHEME FOR QUESTIONS THREE AND FOUR BASED ON THEORETICAL ELEMENTS