INVESTIGATING TEACHERS’ BELIEFS IN THE IMPLEMENTATION OF
SCIENCE INQUIRY AND SCIENCE FAIR IN THREE BOSTON HIGH SCHOOLS

Doctoral Dissertation
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Dedication

It is my absolute desire to dedicate this work to my dear sons, Trystyn and Eitan, and my nieces and nephews, in particular my niece and “daughter” Annie. I hope this work will forever remain an inspiration to you in academic and career endeavors as you ascend the ladder of your lives. Throughout the arduous process of creating this study, I have attempted to pave the way for your own academic advancement. I am no less convinced that this piece of work will continuously revive your pride in me and rejuvenate your academic ambition so that you achieve your full potentials.
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Abstract

In previous decades, inquiry has been the focus of science education reform in the United States. This study sought to investigate how teachers’ beliefs affect their implementation of inquiry science and science fair. It was hypothesized that science teachers’ beliefs about inquiry science and science fair are predictive of their implementation of such strategies. A case study approach and semi-structured interviews were employed to collect the data, and an original thematic approach was created to analyze the data.

Findings seem to suggest that science teachers who embrace science inquiry and science fair believe these practices enhance students’ performance, facilitate their learning experience, and allow them to take ownership of their learning. However, results also implied that teachers who do not fully embrace inquiry science as a central teaching strategy tend to believe that it is not aligned with standardized tests and requires higher cognitive skills from students. Overall, the study appears to indicate that when inquiry is presented as a prescribed teaching approach, this elicits strong negative feelings/attitudes amongst science teachers, leading them not only to resist inquiry as a teaching tool, but also dissuading them from participating in science fair. Additionally, the findings insinuate that such feelings among teachers could place the school at risk of not implementing inquiry science and science fair.

In conclusion, the study reveals that science inquiry and science fair should not be prescribed to teachers as a top-down, mandatory approach for teaching science. In addition, the findings indicate that adequate teacher training in content knowledge and pedagogy in science inquiry and science fair should be encouraged, as this could help build a culture of science inquiry and implementation amongst teachers. This should go hand-in-hand with offering mentoring to science teachers new to inquiry and science fair for 2-5 years.

Keywords: inquiry learning, teacher behavior, behavioral beliefs, normative beliefs, control beliefs, theory of planned behavior, case study.
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Chapter I: Introduction

Research Gap

Statement of the Problem. For more than three decades, professional literature in the field of science education has documented the important role of scientific inquiry strategies, such as science fairs, Olympiads and projects, in increasing achievement and improving students’ retention of science concepts (Minner, Levy, & Century, 2010, p. 474). In the 18th and 19th centuries, scholars noted the significance of experiential learning, direct observational studies, object teaching, activity instruction and child-centered learning as described in the historical works of The Committee of Ten, a group of educators who in 1892 recommended the standardization of high school curricula in America. The recommendations of John Dewey and Foster McMurray are also worth noting, especially with reference to progressive education and child-centered learning (Haury & Rillero, p. 18-20). Similarly, the National Science Education Standards (NSES) recognized that “inquiry into authentic questions generated from student experiences should be the central strategy for teaching science” (Trautmann, MaKinster & Avery, 2004, p. 1), a position that is also held by the Next Generation Science Standards, NGSS (NRC, 2013). NSES were a set of National Research Council (NRC) guidelines for K-12 science education which defined goals for teachers and administrators to set for students and to offer as professional development content, respectively (NRC, 1996). NSES are since being replaced by NGSS, a modern collaborative framework for K-12 science education aiming to produce scientifically literate and effective members of the US workforce (Achieve, 2011).
However, despite widespread recognition of its importance, most science educators today resist the implementation of project-based learning. Many believe that teaching the process of science means sacrificing teaching of the “real” content necessary for students to pass high-stakes standardized tests (Crawford, 2007). In fact, Trautmann, Makinsler and Avery note that the US remains far from the goal of embracing inquiry science as a norm in classrooms, and efforts to attain this objective are obstructed by significant challenges. According to Roehrig and Luft (2004), teachers often misinterpret various scientific inquiry models, thus missing the opportunity to engage their students in science inquiry. As Crawford (2007) explains, over a decade since NSES’s recommendation of inquiry-based science, “it is clear that we are far from attaining our nationally stated goal of a shifting emphasis towards more inquiry-centered K-12 classrooms” (p. 613).

A review of the professional literature as well as my own experience, based on interactions with scores of educators over the preceding two decades, clearly support the contention that scientific inquiry is lacking in America’s classrooms. This may be due to teachers’ inadequate content knowledge and lack of motivation to implement inquiry methods (Minner, Levy, & Century, 2010, p.474). It has also been my experience that most teachers lack both the experience and the confidence to competently conduct scientific research owing to uninformed or misguided beliefs about inquiry science. The social aspects of learning environments also have a significant influence on learning, especially at the elementary and middle school levels. Therefore, the learning environment should be reorganized to facilitate scientific inquiry (Alozie, Birr & Krajcik, 2010, p.396). However, there is still a great deal to learn concerning scientific inquiry in secondary school classrooms since it remains unclear whether the instructional strategies and curriculum driving scientific inquiry at elementary and middle school levels apply to teaching inquiry-based science in high school.
Research is needed to foster a better understanding of teachers’ behaviors in the implementation of scientific inquiry in high school classrooms. Findings will potentially enable education policy makers to understand why education reforms aimed at fostering scientific inquiry, which are indispensable to developing the next cohort of scientific thinkers, have had little impact in practice. It will also help to promote scientific discourse by using science fair projects throughout the school district as a means of helping teachers to instill a deeper level intellectual thought and critical analysis in their students. Additionally, it will develop a repertoire of strategies and resources to support teachers’ shift from traditional teaching practices to 21st century teaching practice—whereby the teacher is the facilitator who models scientific inquiry skills, asks guiding questions and fosters student creativity; and where the students act as problem-solvers rather than simply fact-finders. As Vanderlinde and van Braak (2010) observed, “Building bridges between researchers and practitioners” helps create “new incentives for school improvement” (p. 312). Similarly, by building bridges between classroom instruction and the real world through inquiry, teachers can create incentives for improvement in science education.

**Significance of the Problem.** American science education reform efforts emphasize teaching science for all Americans and identify scientific literacy as a central goal of science education (American Association for the Advancement of Science, AAAS, 1993; NRC, 1996). But when a teacher’s focus is primarily on teaching a set of basic skills rather than critical thinking and knowledge, the needs of modern society in regards to scientific literacy are not being served. This research comes at a time when debate regarding overall education reform in the country is focused on the state of America’s education system in the face of stringent accountability requirements and high-stakes testing as mandated by the No Child Left Behind Act (NCLB) and the present Race To The Top (RTTT) initiative. NCLB has been blamed by many scholars for shifting teachers’ focus to drilling students on test subjects
at the expense of fostering hands-on experiential learning (Trautmann, MaKinster & Avery, 2004, p. 2; Nichols, Glass & Berliner, 2005, p. ii). One could postulate that perhaps such tests exist because unions and schools are reluctant to accept close scrutiny of teachers’ ability, and it is easier to test the students than their teachers.

Our contemporary society requires workers who can problem solve and think critically, and who can meet technological and scientific demands on a global scale. However, many teachers fail to realize that helping students to achieve scientific literacy involves more than just teaching and learning science as a body of knowledge (Akerson & Hanuscin, 2006, p. 654). Achieving this elusive goal also requires helping students to develop an understanding and the ability to apply scientific facts, definitions, laws, theories, and concepts (Tal, Krajcik, & Blumefeld, 2005, p. 725). By teaching science simply as a body of knowledge, i.e., without inquiry, teachers limit students’ abilities and opportunities to challenge established scientific ideas and theories.

Furthermore, we are living in an information age where the availability of information is expanding at an exponential rate. If students do not learn how to access and process this information, they will inevitably be at a disadvantage. Simply memorizing myriad facts is not a very practical approach in today’s world. What is needed is for students to understand how to locate and make sense of all these new facts and quantities of information. Students need to learn how to ask and answer the challenging questions they will encounter in their careers and in life in general. While a lot of research has been devoted to the subject of inquiry science (Prawat, 1992; Wenner, 1996; Tarik, 2000; Proude, 2002; Roehrig & Luft, 2004; Crawford, 2007; Minner et al., 2010), most of these studies have focused on identifying the problem rather than providing practical solutions. The present study sought to analyze teachers’ beliefs in the implementation of inquiry science and science fair with a view to fostering improvement in practical science learning. This was done by scrutinizing
procedures and methods at selected high schools in Boston and extrapolating from there, as suggested by Ronald D. Anderson (2002, p.6).

**Positionality Statement.** Historically, scholars have underscored the significance of experiential learning, direct observational studies, object teaching, activity instruction and overall child-centered learning (Haury & Rillero, p. 18-20). Inquiry-based science encapsulates all this facets of learning. Notably, over the last three decades, the critically important role of scientific inquiry strategies has been a dominant theme in science education professional literature (Minner, Levy, & Century, 2010, p.474). Furthermore, this empirical documentation is congruent with my own observations and conclusions drawn from having served as a science teacher for more than 15 years and as a science program director for over 5 years in Boston’s high schools. Time and again, I was struck by the fact that too many science instructors eschew teaching the process of science, preferring instead to emphasize a more fact-based approach, which they view as necessary for student success on standardized tests. The problem is compounded, according to my observations conducted over many years, with inadequate content knowledge, lack of motivation to implement inquiry, lack of scientific research experience and uninformed belief systems about inquiry.

The National Research Council (NRC) holds a distinct position regarding inquiry science. According to the council, inquiry is “the diverse way in which scientists study the natural world and propose explanations based on evidence derived from their work” (National Research Council, NRC, 1996, Online). This enables learners to engage in science and enhance their understanding of science concepts through their previous ideas and experiences. Thus, NRC strongly believes in and recommends science inquiry as a fundamental strategy for science teaching. The same position is taken by the Next Generation Science Standards (NGSS), although NGSS suggest some ambiguity with the term *inquiry* and tends to deemphasize its use, emphasizing instead the production of scientifically literate
citizens and competent, skilled members of the American workforce (Achieve, 2011). I strongly support NRC and NGSS’s position on scientific inquiry. All through my career as a science teacher, I have endeavored to incorporate science projects/fairs in my teaching. As a science curriculum director, I believe I now stand a better chance to encourage and influence most science teachers under my supervision, to embrace process-based science teaching. The goal of the present study was to support this vision by exploring the issues surrounding teachers’ implementation of science inquiry and science fair, and by suggesting practical solutions to perceived challenges.

One aspect of scientists’ work that I believe is crucial for students to acquire is an understanding of the significance of ethics and conclusions based on data collected through scientific research, because of the implication of scientists’ work to improve individual lives and societies. For example, the racial classification in the early 18th century of the superiority and inferiority of races, which became part of the Western racial ideology, was the result of scientific research involving different human characteristics, which was later falsified (Carlton, 2008). Similarly, western gender stereotypes have biased historical research of gender studies in the south (Fennell & Arnot, 2008), thereby rendering such research limited in its historical significance and material use. Thus, exposing students to authentic scientific inquiry via science fair projects is not only necessary to the student’s academic success, it is also a vital component of the development of critical thinking skills necessary to separate authentic scientific data and research results from potentially questionable results, such as the superiority/inferiority of different races and other biases.

In pursuing this subject, it is important to note the role of teachers’ belief systems in shaping their actions in the classroom. Both from experience and as noted by Wallace and Kang (2004), teachers’ actions in the classroom are significantly representative of their beliefs. Additionally, teachers’ actions in the classroom are influenced by their knowledge
and experiences (Walace & King, 2004). From experience in the field of education, and from literature, for successful implementation of science inquiry, science teachers ought to have strong content knowledge and wide experience in teaching the subject. This equips them to help students develop their ideas by probing at deeper levels. However, many teachers lack this vital experience (Alozie, Birr & Krajcik, 2010). Besides, Davis (2003) noted that teachers also tend to be biased toward employing the same teaching strategies they experienced as students. This makes them less innovative and less creative, particularly in incorporating science fair projects into the curriculum. Furthermore, most teachers’ training – as currently constituted – does not provide an effective model for the practice of science education based on inquiry (Alozie, Birr & Krajcik, 2010). This limits teachers’ competency to conduct authentic inquiry in their classrooms, thereby preventing them from embracing science inquiry projects in their curriculum.

The purpose of this study was to explore and provide working solutions to influencing negative teachers’ beliefs that inhibit their inclination to implement inquiry in science teaching. The study focused on the Boston Public Schools district in which I have worked for many years. This was a valid choice because, as an educator who believes in the benefits of science inquiry and science fair for students, and whose students have experienced successes with science inquiry and science fairs, I wanted to positively impact my (and my students’) experiences in my own district. I undertook this study in hopes of fostering positive changes in our approach to teaching science. I simply felt that I should study my own backyard, so to speak, because I am intimately familiar with the system’s strengths and shortcomings from top to bottom. Not only that, but I dealt with the same student population that participating teachers must educate. Thus, I experienced similar challenges to those that face these teachers when implementing science inquiry and science fair. Nevertheless, in my professional judgment, the benefits of engaging my students in science inquiry and science fairs far
outweighed the obstacles I faced during the implementation phase of science inquiry and science fair.

This study involved high school science teachers in three schools. The participants were surveyed to provide insights into the prevailing state of inquiry science in the schools and the factors that influence the implementation of science fair projects into the curriculum in order to identify possible interventions to support teachers. Since this study involved interviews conducted in the schools, approval was obtained from my institution’s Internal Review Board (IRB), Boston Public Schools (BPS), as well as from leaders in the participating schools. In order to maintain exceptional levels of research integrity and ethics, participants were required to sign a consent form and acknowledging that their participation was fully voluntary. This was preceded by a detailed explanation of the objectives of the study and the intended use of collected data so as to thoroughly inform the participants. Moreover, participants were assured that they reserved the right to opt out of the study at any time and/or for any reason.

I had anticipated that this study would involve the collection of sensitive information from teachers. For instance, I expected teachers to make honest self-appraisals regarding their personal teaching practices, preferences and associated beliefs, some of which may be seen to be compromising the curriculum. Such information, if not protected, may lead to the inadvertent victimization of participants. Therefore, following Creswell’s suggestion (2012, p. 25). I maintained participants’ anonymity by ensuring that the participants’ personal information/identity was not revealed. Instead, codes were used to denote participants and their school. Participants were also assured that the outcome of the study (reports/publications) would be shared with them before publication. Furthermore, in order to ensure that information obtained was as accurate and unbiased as possible, I resolved to
maintain a neutral stance (Creswell, 2012) throughout my engagement with participants to avoid evoking biased responses.

Overall, delving into the lack of inquiry science in our classrooms is a complex problem of practice, the study of which is subject to a wide range of biases and ethical considerations. These biases may be due to teachers’ inadequate content knowledge, experience, and belief systems, as well as the prevailing teaching conditions and accountability requirements. It is imperative to note that this is a sensitive study; thus, to maintain the accuracy and integrity of collected information, all ethical considerations regarding informed consent, confidentiality and protection of participants from potential retaliation were strictly adhered to.

Research Questions

Central Research Question. The central research question of this study is, how do teachers’ beliefs, about science inquiry and science fair, affect the implementation of science inquiry in their teaching, and in particular, their participation in science fair?

Sub-questions. In the context of Iseck Ajzen’s Theory of Planned Behavior (TPB), which states that human behavior is a function of the interaction of three kinds of beliefs – behavioral, normative and control beliefs, the central research question was divided into three specific questions as follows:

1. How do teachers’ behavioral beliefs affect their implementation of science inquiry and science fair projects?

2. What normative beliefs affect teacher’s implementation of science inquiry and science fair projects?
How do teachers control beliefs affect their implementation of science inquiry and science fair projects?

Research Hypotheses

Behavioral Theories as the Theoretical Framework. Research shows that there is a wide range of science teaching styles “as a result of the strong interaction existing between teaching attitudes and competencies, school and society” (Barros & Elia, 1974). By associating teaching style with teachers’ attitudes, Barros and Elia’s notion implies that teaching practice can be considered from a behavioral perspective. As such, this study hypothesized that teachers’ use of inquiry is a human behavior that can be explained (at least understood) using human behavioral theories. Two main human behavioral theories were considered, the theory of planned behavior (Ajzen, 1991) and the cognitive behavioral theory (Glanz & Rimer, 1995), to construct the theoretical framework for this study. TPB was chosen as it accounts for human beliefs as a determinant of attitude, which is identified as an important behavioral factor affecting teacher’s choice of particular teaching strategies.

Teachers’ Beliefs Central to Implementation of Science Inquiry. The selected human behavioral theory (TPB) suggests that human action (behavior) is a result of the interaction among three kinds of beliefs. These include behavioral beliefs, normative beliefs and control beliefs, which interact to determine behavioral intentions and ultimate actual behavior (Ajzen, 1991). TPB is a model that has been extensively researched, and well accepted amongst researchers for its ability to predict human behaviour (Ajzen 2002). Thus, considering science teachers’ choice/use (or lack thereof) of particular teaching approaches as a function of human (teachers’) behavior/action, this study further hypothesized that science teachers’ beliefs (behavioral, normative and control beliefs) about science inquiry are predictive of their implementation of such strategies in the classroom/school.
Science Inquiry Implementation Predictive of Science Fair Participation.

Science fair is largely accepted as an important means of promoting scientific inquiry skills in science learners. This belief implies that teachers who prefer science inquiry method are more likely to engage their students in science fairs. In other words, science inquiry can be seen as a determinant factor in the success of science fair. This study was therefore guided by a third hypothesis that science teachers' beliefs about science fair are predictive of teachers’ participation in science fair.

Theoretical Framework

All research, in some form, contains theory. Theory refers to an organized set of principles and concepts for explaining a given phenomenon (The Research Council of Norway, 2011, p. 3). Theory provides comprehensive and complex conceptualizations of phenomena that cannot be easily pinned down. It also offers a lens for viewing complex social issues and problems (Reeves et al., 2005). In research, theory guides all aspects of the research process from formulation of the research problem and definition of the methodology through discussion of research findings. Additionally, theory may result from the findings of a research undertaking (Creswell, 2012). A theory or a set of theoretical constructs, used to guide a study, constitutes its theoretical framework. This is the part of a study that describes the research questions or hypotheses, the line of inquiry, as well as the methodology adopted to answer/test them. These theoretical constructs offer a lens for researchers to conceptualize various aspects of their fields of study so as to provide a rationale and justification for the study (Ocholla and Roux, 2011). Overall, the theoretical framework is the “backbone” of a research project that not only shapes the research process, but also the underlying principles, assumptions and explanations behind the research. Thus, it should be thoughtfully selected for any research endeavor and explicitly mentioned in any research report.
The Theory of Planned Behavior. The Theory of Planned Behavior, TPB (Ajzen, 1991), constituted the theoretical framework for this study. This theory suggests that human behavior is a function of an individual’s motivation (intentions to perform a given behavior) and his/her ability to exercise control over the behavior (behavioral control). Thus, the theory distinguishes among three levels of beliefs that interact to control human behavior: behavioral beliefs, normative beliefs and control beliefs (Fisanick, 2010). The primary assumption underlying TPB is that individuals command a tangible level of control over their exercise of a given behavior, which defines their actual behavioral control.

Ajzen (2002) defines behavioral beliefs as “the beliefs about the likely outcomes of the behavior and the evaluations of these outcomes which produce a person’s favorable or unfavorable attitude towards a behavior” (Kupucu, 2014, p.1). In other words, behavioral beliefs determine a person’s attitudes/intentions towards a given behavior although it is not a direct measure of one’s attitude toward the behavior (Ajzen, 2002, p. 7). Attitude is perceived as one’s overall evaluation of executing a given behavior. This implies that attitude in turn influences a person’s behavioral intentions and ultimately shapes his/her actual behavior. As already indicated, the resulting attitude may be favorable (implying that the individual will most likely perform the behavior) or unfavorable (meaning the individual is less likely to perform the behavior). In a recent study, Kupuku (2014) sought to characterize physics teachers’ behavioral beliefs about the new Turkish High School Physics Curriculum (THSPS). This curriculum aims at helping students internalize physics as a central goal of physics learning in Turkish high schools. Kupuku noted that most physics teachers believed that THSPS assists students to utilize their skills and develop greater interest in learning Physics, thus making better sense of the concepts involved (p. 141). Furthermore, teachers thought that the new curriculum would help Physics learners to perfect their
inquiry/questioning skills, relate the subject to day-to-day life and come to a better overall understanding of the subject (p. 142). These favorable behavioral attitudes accelerated teachers’ adoption of the new curriculum.

Unlike behavioral beliefs, normative beliefs refer to an individual’s “beliefs about the expectations of others and one’s motivation to comply with these expectations” (Ajzen, 2002, p. 1). According to Godin (1996, p.64), one’s beliefs about other’s expectations strongly influence his/her likelihood of performing a certain behavior. How motivated the person is to comply with other’s expectations may then either facilitate or impede compliance with the expectations. Human behavioral theorists agree that normative beliefs are determined by perceived social/societal expectations and the associated pressure to behave in a particular manner, otherwise referred to as subjective norms, although normative beliefs are not a direct measure of subjective norms (Ajzen, 2002; Bodin, 1996). In a school setting, societal pressures/expectations may emanate from such stakeholders as parents, teachers, students, the schools, and even the state (Kupucu, 2014). These may play a role in determining teachers’ normative beliefs and/or they may be inversely associated.

The third level of beliefs that control behavior is the control level. This level comprises control beliefs, the “beliefs about the presence of factors that may facilitate or impede performance of a behavior and the perceived power of these factors” (Ajzen, 2002, p. 1). These factors can either facilitate or impede the performance of a given behavior. As Kupuku pointed out, physics teachers in Turkey widely believed that the new high school physics curriculum made it easier to teach physics due to several factors: availability of numerous day-to-day examples; widespread internet use; and availability of feasible and interesting experiments, examples and pictorials in the Physics course book (p. 144-145). On the contrary, impeding factors (that made other teachers to believe that it was difficult to teach physics under the new curriculum) include: inadequately equipped laboratories;
university entry examinations; inadequate spread of ICT; overpopulation of students in the Physics classroom; limited Physics coverage by existing ICT; and lack of adequate lesson hours (Kupucu, 2014, p. 145). The greater the perceived influence of these factors on an individual’s behavior, the higher the likelihood of performing the behavior.

Technically put, behavioral beliefs determine (though they are not a direct measure of) an individual’s perceived behavioral control (PBC). PBC describes one’s beliefs for executing a given behavior and reflecting on the perceived factors which, based on their perceived power, may make it easy or difficult for the person to perform the behavior (Ajzen, 2002). Bodin (1996) pointed out that these perceived factors may be external (for instance, time, resources, social support, etc.) or internal (such as one’s skills, ability and information). Again, depending on the perceived power of these factors, one’s level of PBC may vary from total control to absolute lack of control. On one hand, total control is where a person experiences neither any practical constraints nor occasion to adopt a behavior. Under no control, on the other hand, one lacks opportunities, skills or resources to execute a given behavior (Godin, 1996).

According to Notani (1998), the three basic tenets of TPB (behavioral, normative and control beliefs) can further be broken down into six constructs, which collectively represent an individual’s actual control over his/her behavior. These include: attitudes, behavioral intentions, subjective norms, social norms, perceived power and perceived behavioral control. Similarly, Godin (1996) expands the three primary levels of TPB into six levels. According to Godin, behavioral beliefs, normative beliefs and control beliefs interact to result in a fourth level called behavioral intentions, which in turn predicts actual behavior and actual behavioral control. Behavioral intentions are an individual’s expressed behavioral motivations to perform a given behavior with a view to achieving some goals. There are three basic parameters that influence one’s behavioral intentions: favorable attitude towards the
behavior (Aact); favorable subjective norm (SN); and greater perceived control (Ajzen, 2002). It follows that the stronger the three parameters, the greater one’s intention to perform the said behavior will be.

As already stated, behavioral intentions determine one’s actual behavior i.e. actual human action. According to Ajzen, actual behavior is closely determined by one’s actual behavioral control. This makes the last two levels of the extended TPB greatly interconnected. In fact, actual human action may be conceptualized as the sufficient degree of actual control one has over himself when opportunity presents itself to perform a given behavior. This is determined by four fundamental environmental factors summarized as TACT namely, target, action, context and time (Ajzen, 2002). In other words, given favorable target, action, context and time to execute a given behavior, an individual may, or may not, perform the behavior depending on his/her level of actual control over the behavior. Probing this process further resonates back to the perceived power of factors, which constitute the first level of TPB, behavioral beliefs. Thus, it is clearly evident that human behavior is a cyclic process that is controlled by the interaction of the six levels of TPB as discussed.

Although TPB was considered to be the best theoretical framework for this study, it is imperative to note that the theory does not necessarily fully conceptualize the human behavior process in its entirety. Conner (1998) identifies six main points that TPB does not consider, but play a significant role in controlling human behavior. These include: belief salience, one’s past behavior/habits, self-efficacy, moral norms, self-identity and affective beliefs. Conner defines belief salience as a subset of one’s beliefs at a given point in time, which determines the person’s attitude. This influence on attitude translates into behavior, and this is coupled with past behavior or habits, which is also said to have great influence on an individual’s future behavior. One other behavioral factor that TPB does not consider is self-efficacy. Though largely regarded as consistent with PCB (Ajzen, 1991), it is different in
actual sense (Armitage & Conner, 2001). According to Armitage and his colleague, self-efficacy refers to one’s confidence in his/her ability to perform a given behavior. Overall, it is not easy to draw a distinct line between TPB’s PCB and self-efficacy.

Additionally, while TPB considers societal norms as an important determinant of individual behavior, it fails to account for personal moral norms, which also have a strong bearing on one’s behavior. Moral norms, in this context, define one’s personal perceptions of the ethical value of executing a particular behavior (Conner, 1998). This implies that before engaging in a behavior, one may consider whether or not the behavior is correct. Consequently, depending on a personal consideration of responsibility, one decides if he or she should perform the behavior. Also, TPB does not consider self-identity as a salient factor relating to one’s behavior. As Conner further noted, self-perception regarding societal expectations/roles may influence an individual behavior. Lastly, while TPB accounts for the ultimate effect of social expectations on individual behavior, the theory fails to consider the affective beliefs thereof. Affective beliefs are the resultant reactions associated with a particular behavior. In this regard, Conner implies that individuals tend to consider the possible impacts of their behavior before behaving in a certain manner.

In summary, the Theory of Planned Behavior postulates that human behavioral, control and normative beliefs interact to give rise to specific behavioral intentions. These behavioral intentions are, in turn, influenced by the actual or perceived level of control that a person has over his/her behavior. This could imply that while an individual’s behavioral intentions are controlled by his/her three sets of beliefs (behavioral, control and normative beliefs), these beliefs do not dictate his/her actual behavioral performance because the individual has some level of control over his/her behavioral intentions. In addition, as Sparks contends, there are many extrinsic factors at work that determine one’s perceived ease of
Seminal Roots and Application. The Theory of Planned Behavior (TPB) began in 1980 as The Theory of Reasoned Action (TRA) with Icek Ajzen and Fishbein. After a series of independent studies on the relationship between attitude and behavior using Value-Expectancy Theories, Ajzen and Fishbein collaborated to publish TRA as a theoretical construct for predicting one’s behavioral intention at any given time and place (Chen & Liu, 2011). TRA was used to conceptualize all behavioral actions over which individuals have the ability to exercise self-control. Its key component being behavioral intent, TRA posited that “behavioral intentions are influenced by the attitude about the likelihood that the behavior will have the expected outcome and the subjective evaluation of the risks and benefits of that outcome” (Sparks, 1994). This definition implies three basic assumptions underlying TRA: that human behavior is subject to one’s voluntary control; that humans reflect on the consequences/implications of their behaviors before putting them into action; and that as a result, intention and behavior are very closely relate. In other words, TRA held that human behavior is a function of both attitudes towards a given action and the subjective norms concerning the action in question (Ajzen, 2002).

As already stated, TRA assumed that people have the power of control over all their behaviors. However, as Chen and Liu (2011) note, this assumption limited TRA in fully explaining human behavior. This is because there are people who have or feel that they have little power of control over their behaviors. As such, to make TRA more inclusive in explaining human behavior, Ajzen (1991) added a third tenet to it, that of perceived behavioral control, resulting in the development of the Theory of Planned Behavior, TPB.
Unlike TRA, TPB conceptualizes human behavior as a result of the interaction among three kinds of beliefs namely, behavioral beliefs, normative beliefs and control beliefs.

Since its inception in 1991, many influential authors and scholars in a wide range of applications, particularly in psychology and education, have used the Theory of Planned Behavior. For instance, TRA and TPB have been used as powerful tools for predicting technology adoption behavior among individuals (Shareef et al., 2009, p. 544). According to Shareef et al., individual characteristics, defined by one’s beliefs, determine his/her intentions and behaviors by influencing the individual’s attitude. This is the basis upon which TPB and TRA are used to conceptualize technology acceptance behavior, thereby providing appropriate theoretical lenses for understanding global variation of online technology adoption, driven by advances in information and communication technology (ICT).

In education, TPB has been used to study teachers’ behaviors for required student participation in science fair competitions (Fisanick, 2010), among other applications. In his study, Fisanick applied the three tenets of TPB to hypothesize that, science teachers with positive attitudes towards science fairs (behavioral beliefs) require their students to participate in science fair competitions. Similarly, teachers with preferences for competitive classroom learning environments (normative beliefs) were hypothesized to require their students to take part in science fair competitions. In addition, Fisanick hypothesized that the predicted behavioral intentions, and the resulting behavior of teachers who controlled their own (and their students’) participation in science fairs, would require students’ participation in science fair competitions. Further applying the theory to inform his research process, Fisanick discovered that, teachers’ attitudes, preferences and motives for required science fair competitions actually play an important role in determining their students’ participation in these competitions.
Alignment. TPB presented a suitable theoretical framework for investigating teachers’ beliefs in the implementation of inquiry science and science fair in high schools. Under this framework, the implementation of science inquiry was seen as teaching practice that could be considered a behavior. As a behavior, science inquiry implementation (and/or science fair projects implementation) is influenced by several behavioral factors, which can be conceptualized in terms of the TPB. Considering the three tenets of TPB (behavioral beliefs, normative beliefs and control beliefs), it was imperative to identify the respective types of beliefs that could influence teachers’ implementation of science inquiry and science fair projects.

First, the possible behavioral beliefs to be identified were teachers’ belief systems about inquiry, teachers’ past experiences, teachers’ training, as well as motivational aspects available to teachers to enhance scientific inquiry in their classrooms, among others. Collectively, these behavioral beliefs would play a pivotal role in determining teachers’ attitudes toward inquiry science. Secondly, normative beliefs would constitute both subjective and social norms for inquiry science in the school environment; for instance, the role of state-mandated science curriculum requirements, state-mandated tests, and accountability requirements for determining teachers’ practices of inquiry science. Generally, such normative beliefs are important antecedents of the motives behind teachers’ implementation of inquiry science, whether due to recognition of its importance or merely as a curriculum/state requirement. Finally, in addition to the behavioral and normative beliefs, the control beliefs in this case were seen to define teachers’ ability to exercise control over their attitudes and prevailing norms for science inquiry. This then influences their preferences about inquiry-based teaching/learning strategies. Furthermore, the three extended levels of TPB – behavioral intentions, control level, and actual control would also be considered to present a more holistic view of the study.
It was upon consideration of the first three basic/original tenets of TPB that the three specific research questions for this study arose, thus directing the study’s focus to the investigation of teachers’ beliefs about science inquiry and science fair projects in their implementation. These research questions, in turn, informed the themes for my literature review. For instance, the literature review concentrated on the theoretical aspects of related studies concerning teachers’ belief systems for inquiry science and the underlying factors behind them, and the roles of the state and state-mandated education requirements for science inquiry practice. Moreover, the methodology for this study was also shaped by TPB towards materials and methods most suited for studying human behavior, specifically beliefs and associated practices related to science inquiry teaching and learning. As suggested by Creswell (2012), these should be geared towards close researcher-participant interaction such as the use of interviews, questionnaires and observation of teaching practices and artifacts.

In sum, theory plays a significant role in research not only by providing a lens for viewing complex societal issues and problems, but also as a special guide to the entire research process. Given this context, an ancillary goal of this study was to investigate teacher behaviors in the implementation of science inquiry and science fair in three high schools. The Theory of Planned Behavior constituted the theoretical framework for the study. This theory suggests that human behavior is a result of interaction among three kinds of beliefs – behavioral, normative and control beliefs. In its extended form, TPB classifies three additional levels of human behavior namely, behavioral intentions, actual behavior and actual control. In light of these three basic tenets of TPB, the implementation of science inquiry was conceptualized as a teacher behavior influenced by their beliefs about inquiry and science fair projects. This, then, was the subject of the study.
Chapter II: Literature Review

Introduction

In past decades, inquiry has been the focus of science education reform. The National Science Foundation (NSF), the National Research Council (NRC), and the American Association for the Advancement of Science (AAAS) have made tremendous commitments to improve science education. They have invested significant financial resources to develop innovative K-12 curricula, strengthen teachers’ skills, and revamp programs that support science teaching and learning at the school, district, and state levels. Yet most science educators today resist the implementation of project-based learning, since many believe that teaching the process of science means sacrificing the teaching of the “real” content of science necessary for students to pass high-stakes standardized tests. Additionally, teachers’ inadequate content knowledge and lack of motivation to implement inquiry, as well as their lack of experience conducting scientific research and belief systems, often prevent them from engaging students in inquiry.

The diversity of today’s classroom, requires that teachers employ instructional strategies that respect and build on students’ cultural backgrounds, first languages, life experiences, and ways of learning, all of which can vary a great deal, while helping all students learn important concepts and skills in science. The literature reviewed for this work provided ample evidence that inquiry strategies can be a highly effective instructional approach that can help teachers to meet the diverse learning needs of their students. Despite decades of research regarding the value of inquiry-based teaching and learning, the execution of such instructional practices continues to be a challenge for many teachers. The struggle continues to be linked to teachers’ ability to create classroom environments that are inquiry-based while addressing the need to prepare students for high-stakes exams.
As such, the first section of this literature review focuses on the critical review of the meaning of science instruction thorough inquiry. The second part describes the nature of science projects and science fairs based on the literature review. It also explains how science projects and science fairs serve as the link between classroom instruction and work of scientists, as well as the reviewer’s own understanding of science projects and science fairs. The third segment describes the history of science fairs. A fourth section examines the barriers faced by teachers in the implementation of inquiry. The literature review concludes with a discussion of recommendations for teacher professional development and teachers’ training programs.

**Inquiry and Contemporary Science Education**

The need for evidence of effective educational practices as a result of The No Child Left Behind Act of 2001 (2002), requiring high-stakes tests based on national standards, has left many teachers having to choose between teaching inquiry versus teaching to the test. Yet, despite the push for standardized tests as a means to assess science achievement, and reform efforts in science education, few large-scale studies have been conducted to investigate the correlation between inquiry science instruction and student performance on standardized tests.

The effects of scientific inquiry instruction have been investigated extensively. For example, recent studies have examined the effect of inquiry teaching on standardized tests in urban schools (Geier et al., 2008), as well as teachers’ beliefs about inquiry, (Hashwech, 1996; Kang, Mansour, 2004; Saad & Boujaoude, 2012), understanding of inquiry, (Crawford, 2007; Keys & Bryan, 2000), and constraints faced in the implementation of inquiry, (Roehrig & Lugt, 2004).
Science education reform efforts emphasize teaching science for all Americans, and identify scientific literacy as central goal of science education (AAAS, 1993 &1990; NRC, 1996). The National Curriculum Standards for the Social Studies states:

The aim of social studies is the promotion of civic competence...Civic competence rests on this commitment to democratic values, and requires that citizens have the ability to use their knowledge about their community, nation, and world; to apply inquiry processes; and to employ skills of data collection and analysis, collaboration, decision-making, and problem-solving. Young people who are knowledgeable, skillful, and committed to democracy are necessary to sustaining and improving our democratic way of life, and participating as members of a global community (National Council for the Social Studies, 1994, p. 1).

However, when a teacher’s focus is primarily on teaching a set of basic skills, rather than critical thinking and knowledge, this does not serve the needs of modern society. Our society today requires workers and citizens who can problem solve and think critically, and who are able to meet global demands. Consequently, teachers who do not employ inquiry-based science instruction miss the opportunity to realize that helping students achieve scientific literacy involves more than teaching and learning science as a body of knowledge. It also requires helping students to develop an understanding and application of scientific facts, definitions, laws, theories, and concepts to solve problems in their everyday life. Otherwise, students’ knowledge may be limited to acquired isolated knowledge “packages” (Cimer, 2007, p. 25).

Further, achievement of scientific literacy depends on having knowledge of the methods and the nature of science – all of which are obtained through scientific inquiry. Science fair, as defined in this study, is one way of helping students to achieve scientific literacy because through the process of requiring students to formulate their own questions,
designing their own experiments, collecting and interpreting their own data, as well as describing the impact their findings have on daily life/contribution to science and either adding to what scientists already know or discovering something new, students will gain a deeper understanding of the nature of science. As Alvesson and Sandberg (2011) explain, rather than “identifying and challenging assumptions underlying existing theories”, modern researchers more often simply look to “construct gaps in existing literature”, that is, they only look to add their own thoughts to existing theories, but not necessarily challenge the validity of such theories (p. 249). By teaching science simply as a body of knowledge, i.e. without inquiry, teachers limit students’ abilities and opportunities to challenge established scientific ideas and theories.

During inquiry students create hypotheses, engage in collecting data based on observation of events and objects, asking questions, constructing explanation, testing those explanations against current scientific knowledge, and communicating their ideas. Inquiry allows students to actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills (NRC, 1996, p. 2). This is because through inquiry students are able to identify their assumptions, use critical thinking, and consider alternative explanations. By teaching science simply as a body of knowledge, i.e. without inquiry, teachers limit students’ abilities and opportunities to challenge established scientific ideas and theories.

Another aspect of inquiry that is significant to science education reform is the need to prepare scientifically literate citizens. According to Atilla Cimer (2007), the significance of inquiry is linked to Dewey’s argument that:

Citizens in a democratic society should be inquirers with regard to the nature of their physical and social environments and be active participants in the construction of society. They should ask questions and have the resources to find answers to these
questions, independent of external authority. Since there is a shared, collaborative aspect to life in a democratic society, students also need to develop a capacity for communal inquiry and dispositions to formulate questions that are personally significant and meaningful to them (p. 29).

We are living in an age where available information is expanding at an extraordinary rate. If students do not learn how to access and process this information, they will inevitably be at a disadvantage. The ability to memorize a set of facts is no longer the most important skill in today’s world, because facts and new information are discovered at very fast rate. Students need to learn how to access and apply newly acquired concepts or skills to different contexts to allow them to solve problems in their everyday life.

Therefore, inquiry teaching and learning through science fair projects encourage students to test, rethink, and construct their ideas and thoughts. They learn how to evaluate and process information and resources, and use knowledge to make thoughtful decisions in the future. This method of teaching and learning supports National Research Council (NRC)’s recommendations that teachers engage students in inquiry by asking scientific questions, using evidence in responding to questions, formulating explanations from evidence, connecting explanations to scientific knowledge, and communicating and justifying findings (NRC, 2000).

The effect of scientific inquiry instruction on students’ achievement, as well as teachers’ perceived understanding of inquiry is of great importance to science education reform. Therefore, this literature review aims to explore the reasons why science educators do not readily embrace the education reform, which calls for engaging students in inquiry learning such as through science fair. This instructional method will help to create critical thinkers and problem solvers who are central to the next cohort of scientific thinkers. For when teachers spend time developing critical thinking and problem-solving skills through
inquiry, their students will approach new learning creatively and energetically. Science fair teaches students how to learn by supporting their quest for knowledge, and their curiosity about their world, and to make reasoned hypotheses and find evidence to test their hypotheses.

Teachers’ shift from traditional teaching practices to 21st century teaching practice—whereby the teacher is the facilitator who models scientific inquiry skills, asks guiding questions, and allows student’s creativity where they act as problem-solvers, rather than simply fact-finders, is key to improvements in science education.

**Defining Inquiry Science Instruction**

The meaning of inquiry stems from philosophy of learning work described as constructivism by Jean Piaget, Lev Vygotsky, and David Ausubel (Cakir, 2008). The constructivist method asserts that knowledge is created when a learner is actively engaged, both behaviorally and mentally, in the learning process in which he/she changes his/her understanding by integrating or replacing existing knowledge.

In science education, the term inquiry comprises three different components; what scientists do (e.g. use scientific method to conduct experiments); how students learn (e.g. use questioning and critical thinking skills to solve problems); and teaching strategies (e.g. designing and using instructional materials that foster scientific investigations). Regardless, the act of inquiry has a consistent core whether it is the student, teacher or scientist doing the inquiry. The National Research Council (NRC), for example, refers to inquiry as the central strategy for teaching science, and defines inquiry as “the diverse way in which scientists study the natural world and propose explanations based on evidence derived from their work” (1996). In addition, NRC notes that inquiry seeks to create opportunities for learners to engage in science and to build an in-depth understanding based on their previous ideas and
experiences. Further, NRC recommends that teachers engage students in inquiry by asking scientific questions, using evidence in responding to questions, formulating explanations from evidence, connecting explanations to scientific knowledge, and communicating and justifying findings (2000).

The NRC inquiry standards are the accepted method of inquiry-based science instruction. The Standards recommend that students in K-12 science classrooms acquire both “abilities to do scientific inquiry” and “understandings of scientific inquiry” (NRC, 1996, p.121). Ability to perform scientific inquiry means that students learn to identify and pose questions, design and conduct experiments, analyze data and evidence, use models and explanations, and finally communicate findings. Developing understandings of scientific inquiry refers to knowing how scientists conduct their work and the concepts related to the nature of science. In addition, the Standards suggests that inquiry-based instruction will further students’ learning of scientific concepts. Although the Standards provide many examples of inquiry-based instruction, they do not give specific recommendations for how teachers develop inquiry lessons that best support the learners in their classrooms.

Teachers possess their own perspectives on and understanding of inquiry. Even though the Standards imparts useful suggestions for the goal of inquiry in teaching, content for inquiry learning, and few examples of the types of students’ engagement activities, teachers are charged with identifying ways to accomplish these goals. The strategies that teachers use will depend on factors affecting teaching and learning. As such, inquiry as defined by the NRC, is not a specific teaching method or curriculum model, although it may be incorporated within or share common characteristics with other instructional models.
Defining Science Fair

Science fair is a competitive event, mostly for school children, in which student-generated science projects are exhibited and judged for a prize. Science fair projects provide students with opportunities to apply scientific methods while conducting independent research and play a fundamental role in helping students make sense of the scientific process (Syer & Shore, 2010). In this study, the science fair project was considered as an effective tool for encouraging science inquiry amongst high school students. Science fair projects advocated by this study are those that encourage students to engage in research consistent with the NRC five elements of inquiry: Learner engages in a scientifically oriented question, learner gives priority to evidence in responding to questions, learner formulates explanations form evidence, learners connects explanation to scientific knowledge, and learner communicates and justifies explanations (NRC, 2000).

The search for literature on the history of science fair yielded one accessible dissertation by Lisa Jean Walker (2003). According to this work, science fair may have started in 1950 by the Science Service organization that sponsored it. Its origin was not stated in a single piece of literature, however it was incorporated into the work of different institutions where it played a small role. In addition, the history of science fair was also embedded in the history of science clubs (p. 74-75).

Walker’s (2003) initial search of literature about the origin of science fair led her to the 1921 dissertation work of Morris Meister, The Educational Value of Certain After-School Materials and Activities in Science, which provided an explanation of the educational activities of science clubs. This work resulted in Walker’s assertion that early ideas of science fair as competitions and exhibitions originated from the science club design, which included activities similar to science fair. Walker’s search produced literature that described science fair as a competitive event rather than an educational practice (p. 77).
Walker’s (2003) attempts to uncover the origin of science fair prompted her to reflect on the only available published work about the origins of science fair—the work of Meister and the published documents about science clubs. Through the literature reviewed, Walker questioned whether science fair originated from the American Institute of the City of New York, the first sponsor of science fair, or in 1928, when the first event was held. Her quest resulted in her identifying other key players in the dissemination of science fair nationwide. This took 40 years, and involved leaders in science education such as the Science Service, American Association for the Advancement of Science, National Science Teacher Association, and National Science Foundation—all of which are strong supporters of science fairs (p. 98).

**Inquiry and Teachers’ Knowledge and Beliefs**

As Gess-Newsome noted, knowledge is empirically based, rational, non-emotional, well structured, and gradually developed (Gess-Newsome, 1999). Knowledge of biology, physics, chemistry, or any other earth science, includes the “epistemological assumptions one makes about a particular domain of inquiry – assumptions about the origin of knowledge, how it is exchanged, and how truth is established within the disciplinary domain” (Prawat, 1992, p. 365). Thus, knowledge is the technical know-how, which is unique to an individual and is typically acquired through experience. In comparison, beliefs are highly subjective and have a substantial emotional component, including attitudes, which are derived from significant episodes experienced by a person (Richardson, 1996). Teacher beliefs emanate from numerous personal experiences in and out-of-classroom as well as experiences and feelings about students’ character (Luft *et al.*, 2003).

Moreover, beliefs influence many decisions made by a teacher, and yet it is difficult to fully understand how practice is impacted by beliefs (Luft, 2001). In addition to having
individual beliefs, teachers have complete belief systems, which may be difficult to change and are more powerful as compared to knowledge of teachers in shaping their decision-making (Brayan, 2003). Furthermore, the beliefs of a teacher may be nested and complex, and as determined by Brayan (2003) in a high school teacher’s case study, could constrain the ability of the teacher to enact inquiry-based decisions affecting his/her mode of teaching, especially teaching science to students.

Research indicates that teachers’ ingrained belief systems about science play a significant role in shaping their instructional behavior patterns (Plourde, 2002). This, coupled with inadequate science background and negative attitudes, has been cited as an obstacle to the effective teaching of science (Tarik, 2000). In a study by Prawat (1992) and Stephen and Wenner (1996), it was revealed that high school teachers generally have low levels of factual and conceptual scientific knowledge and inadequate skills in the science content area. Prawat, as well as Stephen and Wenner agree that this is greatly responsible for teachers’ hesitancy in teaching science through inquiry. This could be the reason teachers struggle to motivate and engage students in project-based learning such as through science fair projects. It also raises the question of whether the inadequately equipped science teachers can manage to produce, out of America’s children, the required pool of scientists and professionals to meet the country’s growing needs and future demands!

It is interesting to note that in the 21st century, America remains far from embracing the inquiry-based approach as the norm for classroom practices and efforts towards this end are obstructed by formidable challenges (Crawford, 2007, p.613). According to Roehrig & Luft (2004), “teachers often misinterpret various scientific inquiry models, thus misrepresenting science as inquiry” (p.4). This implies that American high school teachers still cling to more traditional beliefs and the outdated knowledge that hinders their use of science fair projects.
In order to better conceptualize its influence on teachers’ classroom practices, it is important to understand what constitutes belief systems. According to Pajares (1992) and Judson (2006), teachers’ belief systems consist of a myriad of interacting, overlapping, and intersecting beliefs inherent in the teachers (Pajares, 1992; Judson, 2006). Hermans et al. (2008) also noted that “belief systems consist of an eclectic mix of rules of thumb, generalizations, opinions, values, and expectations grouped in a more or less structured way” (p.150). Herman’s assertion could mean that belief systems involve stereotypes, which may (or may not) be a true reflection of reality. Haney et al. (2002) sought to investigate how teachers’ beliefs predict their succeeding classroom action. In a cross-sectional survey of high school teachers across America, Hanley et al. established that, generally, teachers having more traditional beliefs implement low-level scientific inquiry as opposed to teachers with constructive beliefs, who implement high-level or more student-centered learning. Furthermore, traditional beliefs discourage the use of scientific inquiry while modern and constructive belief systems encourage implementation of process-based science. Unfortunately, this study does not clearly define what entails “traditional” or “modern” belief systems.

In addition to its influence on implementation of scientific inquiry, teachers’ knowledge and beliefs are vital for the creation of a favorable classroom environment in which students develop deeper understanding of how scientists process knowledge of the present world (Crawford, 2007; Roehrig et al., 2007). Knowledge and beliefs concerning teaching are inextricably linked, because what a teacher believes about teaching, to a great extent, hinges on his/her knowledge of the discipline and the beliefs of how students learn (Roth et al., 1998). It is, therefore, reasonable to assume that what a teacher knows and believes impacts his/her lesson planning and delivery. For instance, a physics teacher
acquires the foundation of his/her discipline-specific knowledge through job related experiences, academic coursework, and everyday informal experiences.

Then, as pointed out by Crawford (2007, p.616), the teacher’s views of the subject matter regarding what science is and is not, coupled with “reform-based pedagogical strategies,” shape the structure of the lesson choice. Knowledge of the pedagogy and subject matter also influence the teacher’s response to students’ inquiries and questions in a science classroom (Crawford & Lunetta, 2002). Overall, similar to a sculptor using clay and tools to mold a person’s image, a science teacher draws from the depth of his/her knowledge of science concepts, pedagogical strategies, students’ developmental level, curriculum, students’ ability to conduct investigations and interact with each other, and the school context.

Most recently, research on novice science teachers has offered new insights into teacher beliefs. As Minner et al. (2010) noted, there is a lack of connection between the beliefs of beginning teachers and their practices. Specifically, many new science teachers hold student-centered beliefs but exhibit teacher-centered practices in their classrooms (Hughes, 2005). Simmon et al. (1999) defined student-centered beliefs as “beliefs that stress the nature of science as negotiated understanding and inquiry, and the construction of science concepts with students” (p. 10). On the other hand, teacher-centered beliefs stress the factual and descriptive nature of science “as determined by the teacher and transmitted to the student” (p.10). The critical difference between the two belief systems lies in their impact on student learning. Teachers who adhere to student-centered precepts shift the responsibility of processing and acquiring scientific knowledge onto the student. Such students actively construct knowledge on their own. But teachers having teacher-based beliefs consider this to be their responsibility in conveying scientific knowledge to students.

Whether used to transmit factual or conceptual knowledge, teacher-centered approaches tend to deprive students of the responsibility to construct their own knowledge.
Most beginning teachers fluctuate between student-centered and teacher-centered beliefs, making implementation of inquiry-based lessons more challenging. However, beginning teachers’ practice is often teacher-centered, with the primary foci being lesson planning, learning content, and classroom management; they are basically concerned with maintenance of classroom, presentation of content, and survival (Adams & Krockover, 1997). From experience, the lack of student-centered approach to teaching remains an obstacle to implementation of science inquiry strategies and science fair projects.

As Luft (2001) disclosed, another aspect of teachers’ belief systems that influences inquiry learning is the common belief that the use of textbooks in classrooms is the only applicable option. However, Luft challenges this textbook-centered approach on the basis that it offers few to no opportunities for hands-on science activities. Though textbook activities are very explicit and tend to be “cookbook” in nature, directing students to perform particular activities or assignments --- and more often confirm what has already been stated in the text – they rarely engage students in deriving their own conclusions or hypotheses about the phenomena (Haury & Rillero, 1994; Miguel, 2015). In contrast, inquiry-based programs are “dynamic, depicting science as an ongoing process of exploration and discovery, rather than a content domain to be memorized” (Mastropieri & Scruggs, 1994, p. 11). Deeper understanding of the majority of science concepts relies on inquiry-oriented instructions that engage students in the investigative nature of the subject. Important skills such as data recording, measuring, and communication are often laid down in textbooks, but higher level skill processes such as inferring, predicting, experimenting, hypothesizing, identifying, and controlling variables can only be taught and reinforced through activity-based experiences (Miguel, 2015; Mastropieri & Scruggs, 1994). Therefore, it is not that textbook-based programs are not useful, but such should be complemented by hands-on experiences consistent with NRC five elements of science inquiry, thus, the teaching of science becomes
real, not simply theoretical. Furthermore, inquiry goes far beyond simply asking questions, and according to the National Research Council (NRC), “inquiry is the state of the mind and involves inquisitiveness, enabling students to learn the concepts and principles of science and acquire the procedural and reasoning skills of scientists as well as understanding the nature of science as a particular form of human endeavor” (NRC, 2000, p. xii). It allows students to extend the investigative process to grapple with data and make sense of observations by applying reasoning and logic. In sum, it is quite clear from the discourse above that teachers’ knowledge and beliefs vary greatly with regard to use of science fair projects, and with lack of support, science teachers may hold on to their preconceived traditional beliefs and, thus, not be inclined to acknowledge the benefits of engaging students in scientific discourse.

**Inquiry and Teachers’ Content Knowledge**

As already stated, teachers’ belief systems have tremendous influence on adoption of inquiry science. This is often closely linked to other impediments to science inquiry such as inadequate content knowledge and insufficient scientific research experience. It is hardly surprising, that research findings link lack of scientific background knowledge to reduced instructor’s capacity to handle students’ unexpected behaviors when using hands-on approaches (Stevens and Wenner, 1996; Kapucu, 2014). This is to say that effective teaching entails more than just teaching science as a discipline. Instead, it needs its own teaching techniques, such as through science fair projects. As stated by Vaidya (1993) in her comprehensive research findings, “…hence, teachers’ science content knowledge, as well as their pedagogical content knowledge, are both issues of concern” (p. 63). It is only until teachers fully understand the science content that the outcome of student learning will undoubtedly change for the best. Professional development that provides opportunities for teachers to engage in authentic scientific inquiry activities will ensure that teachers become
more comfortable with implementing scientific inquiry with their students (Kapucu, 2014). This, from experience, enhances teachers’ content knowledge and pedagogy.

Teachers also need to understand both the nature and structure of science, and be capable of translating content into learning activities. Though teachers may possess an academic degree from prestigious universities, many have poorly organized and compartmentalized knowledge of subject matter (Talbert et al., 1993; Roofe & Miller, 2013). Moreover, the preparations assigned to teacher, especially beginning teachers, further compound the problem; they are frequently given excessive preparations and, as a result, are likely to teach outside their specialty science area (Hughes, 2005). Such teachers are more likely to possess fragmented and limited subject matter knowledge, making them rely heavily on prescribed curricula and texts (Brickhouse & Bodner, 1992; Roofe & Miller, 2013). There appears to be a correlation between the instructor’s views regarding the nature of science and classroom practice. Teachers who have a positivist view of science often possess a transmission outlook of teaching science. In contrast, teachers with a progressive view of science are more likely to espouse constructivist’s learning outlook (Hughes, 2005). Although several earlier studies found that most teachers have positivist views, it is worth noting that the majority of teachers do not subscribe to one philosophical position (Mellado, 1997); some might hold contemporary views in certain aspects in regard to the nature of science, and more traditional or inadequate views in others. The extent and nature of the relationship between the conceptions of science and the actual classroom practice of teachers is complex, and disagreements persist among scholars (Minner et al., 2010). The lack of amicable consensus among scholars demonstrates the complex nature of the issue, raising concern that the topic requires comprehensive and additional consideration from researchers.

Also, knowledge of the science context to be taught is critical to effective teaching. Preparation and implementation of inquiry-based strategies in teaching requires a well-
rounded understanding of both the students as well as classroom environment (Anderson, 2002; Windschitl, 2003). However, new teachers have limited practical classroom knowledge and minimum experience with students. Furthermore, these teachers are particularly susceptible to the reactions and influence of their students. The reactions of students to instruction are key components to successful efforts by novice teachers. Positive student response to a teacher’s efforts increases the likelihood that the teacher will continue that instructional approach (Windschitl, 2003, p.9). Nevertheless, negative student response may persuade the teacher to completely abandon the current approach and opt for alternate teaching methods, including traditional ones (Loughran, 1994). Moreover, as Brickhouse (1990) cited, students’ negotiation of work and competitiveness over grades directly influences the course of a lesson (p.12). Generally, teachers, more so beginners, face a broad range of constraints to implementing inquiry-based strategies. The United States, to a great extent, is culpable of these constraints, which prevent implementation of inquiry-based strategies. As Minner et al., (2010) state, “if the US is ever to assume a global position as first in the fields of science and mathematics, it would seem that progressive changes need to occur in teacher education programs” (p.475). Therefore, the US education system desperately requires progressive reform, and those constraints faced by teachers in implementing inquiry science education should be properly addressed in order for students to enjoy the realities of science.

**Inquiry and Teachers’ Attitudes**

In addition to teachers’ belief systems and content knowledge, teachers’ attitudes significantly influence their classroom practices, particularly with regards to scientific inquiry. In a study to assess teachers’ attitudes towards science as a teaching subject, Nabors (2000) found that more than half of high school teachers find teaching science via the use of
science fair projects very threatening, and ranked science at the very bottom of their preferred subjects to teach. A similar study by Tarik (2000) also revealed that the descriptors used by teachers to describe their feelings concerning science teaching were significantly negative. Tarik associated these negative feelings to reduced self-efficacy of teachers who had experienced high achievement in science (Tarik, 2000; Akalin & Sucuoglu, 2015).

This is in sharp contrast with the attitudes renowned scientists, such as Richard Feynman and Albert Einstein, who would testify that “scientific play” was a critical part of their childhood development, and persistent playfulness contributed to their scientific knowledge and ultimate success in their careers. In fact, Feynman once said, “I play with physics whenever I want to, without worrying about any importance whatsoever,” leading to discoveries that resulted in his earning a Nobel Prize (Feynman, 1985, p. 157 cited in Jarret, 1998; Akalin & Sucuoglu, 2015). Science and “play” are often partners in invention and research. The interest and enjoyment that come from manipulating and playing around with scientific phenomena build positive attitudes towards learning in all fields (Stevens & Wenner, 1996, p. 11). Though teachers/people are not born scientists, it is only when they cultivate interest and find science fascinating and worth playing with that they will engage students in scientific inquiry.

**Inquiry and Science Curriculum Materials**

Lack of proper curriculum materials has also been cited as a key instructional constraint to implementation of inquiry-based science. Studies indicate that existing laboratory manuals, curriculum materials, and textbooks offer a limited number of activities that develop inquiry skills, and generally lack constructivist activities (Minner *et al*., 2010; Ginns & Waters, 1990; Spicker & Hernandez-Azaranga, 2007). Though it is quite possible to reconfigure such curricular materials, novice teachers are typically lacking in the classroom
knowledge and time to implement inquiry-based learning (Beck et al., 2000). In an inquiry-based learning classroom, the teacher focuses more on helping students identify and answer their questions, and less on communicating what he/she knows to students (Hughes, 2005). This type of teaching requires strong classroom management structures and effective instructional models.

Generally, institutional constraints significantly obstruct the implementation of inquiry-based strategies. Unlike the other factors – teachers’ belief systems, content knowledge and attitudes – availability of appropriate curriculum materials is an extrinsic factor, which is not under the control of teachers. Instead, it is the responsibility of school administrations, districts, states as well as the federal government to provide teachers with necessary teaching materials. Thus, whereas teachers have a direct influence on the practice of inquiry, it is evident that schools administrators also have a critical role to play in support of inquiry, though indirectly.

Science Projects and Science Fairs

The main goal of science education is to teach students to reason scientifically by engaging them in authentic inquiry activities designed to promote independent and critical thinking. Through authentic inquiry, students generate their own scientific research questions, propose procedures to address scientific questions of interest, and identify or create models designed to address the scientific research question(s) at hand (NRC, 1996). Inquiry through science fair projects, rather than traditional “cookbook lab” methods of science teaching and learning, in which students follow a predetermined protocol and the results of the experiment are known in advance, allows students to more fully engage in critical thinking and learning.

Further, only inquiry, science projects, and science fairs specifically, help students better develop and understand the need to engage in probing questions to scientific problems.
This, in turn, affords students increased opportunities to propose and develop their own methodologies, and increases their scientific literacy skills to apply newly acquired concepts or skills to different contexts. Thus, science projects and science fairs are a key link between science education and the work of scientists in real life. Both science projects and science fairs engage students in developing and employing scientific reasoning and science skills to construct new content knowledge and encourage students to pursue scientific careers (Abernathy & Vineyard, 2001; Akalin & Sucuoglu, 2015).

For this literature review, science projects and science fair projects are being defined as any type of authentic inquiry activities in which students design and conduct their own experiments, regardless of whether these projects are being considered for science competitions normally associated with science fair projects. However, the definition proposed in this work does not imply that the projects being referred to do not qualify or cannot be entered into science fair competitions. Science projects and science fair projects are being referred to as students’ authentic investigation projects, in which students have the opportunity to learn science by doing science similar to real scientists, as opposed to carrying out experiments that follow cookbook recipes that barely resemble investigations conducted by scientists in real life (Roth, 1995; Schwartz & Crawford, 2004). Students select a challenging and open-ended problem that is based on real-life situations instead of a more abstract or ideal situation. Learners’ work is open-ended in the sense that multiple approaches can be used to obtain many different and perhaps competing results. Students do not simply follow a series of pre-determined steps such as those found in laboratory manuals commonly used in science curricula, but rather they examine a problem they identify, using higher-order thinking skills and different resources and perspectives.

The definition of science projects and science fair projects provided in this review is being proposed with the complete awareness that traditionally, these are long-term research
projects, which are difficult to implement due to the many constraints of most science courses. As such, the implementation of science projects and science fairs to create opportunities for learners to engage in science and build an in-depth understanding based on their previous ideas and experiences, (NRC, 1996) can simply involve the modification of common laboratory activities to include inquiry strategies (Trautmann, MaKinser, & Avery, 2004). Modifying laboratory activities addresses the inquiry implementation constraints described previously.

Furthermore, in this literature, science projects and science fairs being referred to may also take the form of inquiry projects resulting from research apprenticeship, extra-curricular science programs, and classroom-based student-scientist partnership. Such projects promote robust understanding of the nature of science, scientific ideas and principles, as well as promoting career aspirations in the sciences (Sadler, et al, 2010). A study by Stake and Mares (2005) indicated that students reported that their research experience changed their feelings about science. Students also reported an increase in their confidence and beliefs in their abilities to do science. Another study by Charney et al. (2007) documented significantly increased discipline-specific content knowledge as measured through open-ended essay questions from Advance Placement biology exams. Their results suggest that engaging students in authentic scientific inquiry can influence their understanding and beliefs. Students become more equipped to “generate hypotheses, consider alternative hypotheses, implement models and logical argumentation in explanations, connect ideas, extend concepts, and ask questions” (p. 195).

Additionally, this literature review acknowledges that while science fair research experiences provide opportunities for students to expand their content knowledge, science projects or science fair projects conducted superficially will undoubtedly result in minimum gain in content knowledge. Such projects may lack in-depth background research, and
contain minimal trials and data analysis. In addition, the discussion of the findings of such projects may lack reference to previous studies or connection to current scientific concepts, components necessary to promote conceptual understanding. For instance, Bleicher (1996) reported that although students in an apprenticeship demonstrated some evidence of learning, detailed analysis of the students’ work revealed limited growth of conceptual understanding, far more limited than the program developers had intended. However, this finding was based on students’ engagement in a short research experience lasting only a few weeks, as opposed to longer-term research experience advocated in this review. As such, when science projects or science fair projects are viewed as long-term project rather than as an extra-curricular activity conducted in a short period of time and/or exhibiting the above-mentioned traits, the gain in content knowledge is bound to dramatically increase.

The Science Fair Movement has been regarded as a valuable component in the scientific arena for over 50 years (McNeill & Crack 2008). It was initiated to accommodate the academic achievements of school children pursuing the academic field, and thus secure their public recognition (Ginns & Watters, 1990). Over the years, many organizations and corporations have joined hands to support its course. This has led to their spread nationally and internationally; however, not all of the generous awards to students reflect the grass roots educational accomplishments (Hodson, 2003). It is worth noting that the emphasis on prizes and rewards at the fairs, as opposed to intellectual cooperation, misrepresents the true essence of science. As noted by Haury and Rillero (1994, p.11), students’ work independently on their projects and prizes are awarded in “wholesale amounts.” Perhaps it could make more sense for science fairs to be structured and conducted on the basis of objective criteria. Participants and students should also be encouraged to work in pairs and teams whenever feasible, and completed projects should be displayed in classroom, district, regional, state and national fairs (Duschl & Hamilton, 1998; Akalin & Sucuoglu, 2015). Science teachers and
individuals with science background should judge the projects to ensure objective and sound evaluation of all projects.

**Conclusion**

Today, although inquiry-based learning is central to science education reform, the majority of science classrooms have students who continuously receive “parcels of pre-packaged knowledge from their teachers through direct transmission and/or carefully orchestrated learning activities” (Sadler, T. et al. 2009, p. 235). For decades, the scientific and educational communities have agreed that science should be taught using the inquiry model. Engaging students in authentic open-ended inquiry requires a teacher to have effective strategies, confidence, an understanding of real life application of science, scientific research experience, and a sound grasp of the knowledge of inquiry. As Hoang (2010) explained, “until teachers themselves develop competency at conducting science inquiry investigation, analyzing and graphing data, and constructing claims in a canonical fashion, there will be little opportunity for their students to participate in projects which allow them to gain clear competency at those practices” (p. 636). As such, teacher preparation programs, as well as teacher professional development, must provide opportunities for teachers to construct their own knowledge and understanding of effective instructional practices. They must also allow teachers to develop their own theories of inquiry teaching and learning, by providing them with research field experiences. These experiences foster collaboration with scientists who can support teachers with lesson modification and lab activities so as to include more authentic inquiry. For instance, Dresner and Worley (2006) reported that teachers’ participation in ecology research experiences strengthen their confidence in conducting biology projects with their students, and contributed to significant changes in their classroom practices. Participants also reported that the collaboration with scientists influenced them to continue to address science education reform initiatives (p. 7).
Chapter III: Methodology

Introduction

Despite the widespread acknowledgement of its importance by professional education standards and literature, the US remains far from embracing inquiry science as a norm in the classrooms, and efforts to do so are faced with formidable obstacles (Trautmann, MaKinster & Avery, 2004). This study sought to investigate teachers’ behaviors in the implementation of science inquiry and science fair projects in three Boston high schools. The critical research question, which the study hoped to answer is: how do science teachers’ beliefs about inquiry science and science fair influence their implementation of scientific inquiry? To answer this central research question, a multiple case study approach was employed to generate a multi-faceted analysis of high school science teachers’ behaviors regarding scientific inquiry. This chapter outlines the theoretical and epistemological perspectives for the study. The chapter further explores the research methodology and approaches utilized in the research.

Research Approach

Qualitative vs. Quantitative Approach. Yin (2003) distinguishes between quantitative and a qualitative research with respect to the methodology employed. Yin asserts that while qualitative research emphasizes the social attributes of a phenomenon and the relationship between the researcher and the phenomenon under study, quantitative research is concerned with the causal relationship between variables associated with the phenomenon under study. Snape and Spencer (2003) add that qualitative research is an interpretative/naturalistic approach geared towards delineating the meaning people attribute to a given phenomenon within their social settings. According to Bryman (1988), the choice of a specific methodological approach is dependent on the appropriateness of the approach to answer the given research questions (Bryman, 1988). This study adopted a qualitative
research design to explore science teachers’ beliefs about science inquiry and science fair projects and to what extent these beliefs affect their teaching practices.

**Inductive vs. Deductive Approach.** Qualitative research approach can be further classified into either inductive or deductive methods. The deductive approach entails a process by which the researcher develops a theory/hypothesis and then designs a research strategy to test the formulated theory (Saunders et al., 2003). In other words, the theory/hypothesis informs the research strategy to be adopted to test it. Inductive approach (also known as theory building), on the other hand, requires the researcher to start by collecting data and then developing a theory (Yin, 2003). This study adopted the inductive research design. As Crawford (2007) asserts, the inductive approach triggers more explanations on a particular subject from the respondents. This approach would facilitate development of meaning/theory from direct observation of teachers or their interaction with the researcher.

**Theoretical Approach**

Any research method should be distinguishable in its epistemological and theoretical perspectives. Epistemology is the way of understanding and explaining “how we know what we know” and it provides the philosophical grounding for interpreting the possibility of knowledge and how to ensure that information gathered is adequate and legitimate (Creswell, 2013). According to Dawson (2002), epistemology is the study of knowledge, and it is more concerned with identifying the origin of knowledge, i.e., the constructionist approach. Applying this framework, the role of the researcher is to understand, reconstruct, analyze and critique participants’ views, the synthesis of which results in meaningful findings (Flyvbjerg, 2011). As Schutt (2006) observes, epistemology rejects the objectivists’ perspective of
knowledge, which emphasizes how different stakeholders construct their beliefs (Schutt, 2006). This research embraced constructionism as an epistemological underpinning to understand high school science teachers’ beliefs, and the effect of such beliefs on their implementation of inquiry-based science practices.

As already stated, it is essential to consider any research endeavor in its appropriate theoretical context. Theoretical perspectives refer to the philosophical stances, which inform the methodological approach by providing a context for its implementation with grounded logic and various criteria. There is a wide array of philosophies from which to choose, e.g., positivism, post-positivism and Interpretivism (Merriam, 1988). For this study, two relevant philosophies were selected, Interpretivism and Phenomenology. As Merriam notes, it has been empirically demonstrated that social reality can be constructed as a continuous process of interpretation and reinterpretation of the intentional and meaningful behavior of people. In other words, an interpretivist seeks to understand the meaning of social situations from the perspective of those who live and experience a given situation (Schwandt, 1998). As such, this study employed the interpretivist approach to understand teachers’ behaviors in the implementation of inquiry-based science strategies. The method would also help to generate vivid descriptions of teachers’ experiences concerning inquiry-based science.

Unlike interpretivism, Phenomenology is a theoretical perspective that employs relatively unstructured data collection methods and follows an inductive approach. Titchen and Hobson (2005) posit that Phenomenology is the study of live human phenomena within everyday social contexts in which they occur from the perspective of those who experience the phenomena. Thus, a researcher should work towards exploring new meanings and increasing phenomenological understanding of different thematic underpinnings. This approach, therefore, was used to complement the interpretivist framework to learn from teachers’ own accounts and experiences with inquiry-based science.
Methodological Approach

Creswell (2013) describes research methodology as the strategy, plan of action and underlying process behind the choices and utilization of particular methods, as well as linking of the choices and use of the methods to determine outcomes. The choice of a given research method should reflect the researchers’ theoretical perspective and attitude on a particular subject (Creswell, 2013). In this study, the case study approach was used to investigate teachers’ beliefs in the implementation of inquiry science. As Robson (2002) pointed out, a case study is a research strategy that entails empirical investigation of a particular contemporary phenomenon within its real-life context. The approach makes use of multiple sources of evidence. The case study approach has a distinct advantage over other research strategies when the “how” or “why” questions are to be answered to discover different factors affecting science teachers in their environmental (teaching) context (Creswell, 2013). The case study approach provides for use of multiple sources of data to explore the relationship between science teachers’ beliefs and their behavior for/against science inquiry. This in turn fosters the validation of data through triangulation (Creswell, 2013) thereby enhancing the accuracy of the resulting findings and conclusions.

Sampling Strategy. The sampling strategy for a given study should be relevant, complete, precise and up-to-date (Baxter, 2008). Overall, sampling strategies are classified as either probabilistic or non-probabilistic. In probability sampling, each member of a study population has an equal chance of being selected (Stake, 1995). Non-probability/purposive sampling, in contrast, refers to sampling techniques in which each member of the study population has an unknown chance of being sampled. Instead, specific features of the population are used as the main factors governing the sampling process. Merriam (1988)
prefers purposive sampling for small-scale, in-depth studies. Denzin and Lincoln (2011) further note that under purposive sampling, personal judgment is used to select cases that will best answer the research questions and objectives. In this study, the purposive sampling technique was used to select research participants (science teachers) who can best represent the prevailing teachers’ beliefs about inquiry science. The selection was based on such factors as willingness to participate, length of teaching experience (at least three years), and science subjects taught.

**Data Collection Methods.** Semi-structured interviews were employed in this study to collect participants’ data. The researcher conducted a total of eight sixty to seventy-minute individual interviews with eight teachers from three different high schools located in the city of Boston. The interviews were conducted after school in the respective schools over a period of two weeks. A predetermined set of open-ended questions was used to explore science teachers’ beliefs about scientific inquiry. At some instances, the interviewees were also asked follow-up questions based on their responses. As Creswell (2013) notes, this allows new ideas and themes to be brought up during the interview session based on the interviewee’s previous testimony. In other words, the semi-structured interview approach enables the researcher to explore normative beliefs that constitute both subjective and social norms for inquiry science in the school environment.

**Data Analysis**

This section describes the theoretical grounding adopted for the data analysis, as well as its practical implementation.
**Theoretical Grounding.** Gray (2004) identifies two main approaches for analyzing qualitative data: grounded theory and content analysis. While content analysis involves identification of specific categories and criteria to be followed prior to the analytical process, Grounded Theory does not follow any predefined criteria (Creswell, 2013). Analysis of qualitative data using grounded theory involves three stages: open coding, axial coding and selective coding. In open coding, data is thematically categorized into units, each of which is related to the research questions (Denzin and Lincoln, 2011). Axial coding is then used to develop relationships between thematic categories; and finally, selective coding helps to integrate core categories to produce a theory. This study adopted a constant comparison approach that is distilled from the grounded theory method (Merrian, 1988). The semi-structured interviews were transcribed, coded, thematically categorized and subsequently compared.

**Practical Implementation.** This study designed and implemented an original approach to analyzing data that minimizes inherent biases related to qualitative study in accordance with the theoretical grounding identified in the first chapter above. The methodology practically implements Ajzen’s TPB model (2002) in four steps: first, interview data was collected and preprocessed using structured interviews as mentioned; then, the data from individual participants were encoded based on a template designed specifically to incorporate TPB, followed by a thematic categorization of all participants’ data, after which followed the actual data analysis and reporting.
Data Collection and Pre-Processing. For all the eight participants, interviews were recorded with the same professional voice recorder. A professional transcriber from a private company then transcribed the recordings; participants’ data were anonymized prior to sending them to the company. All transcripts were verified by comparing the electronic files produced by the private transcript company with the actual recordings. This helped to identify and correct a few minor discrepancies. Finally, the corrected transcripts were sent to corresponding participants for a final review; participants had an opportunity to amend and clarify their ideas and responses. Three respondents clarified their statements by either adding new comments or revising/expanding their previous responses. The participants then sent the transcript with their edits back to the researcher via email. Five participants acknowledged through email that they had, in fact, read the transcripts and agreed with the content in its entirety.

Methodology for Coding Individual Participant Data. A visual map representing an exact and detailed description of the TPB (Ajzen, 2002) was created, as illustrated in Figure 3-1. The first part of the figure is called idiosyncrasy; it summarizes all data related to participants’ specificity (demographics, educational history and teaching experience). The figure then describes the six components of Ajzen’s TPB model (2002): the behavioral, normative, and control levels, followed by the behavioral intention, actual behavior, and finally actual control.
Figure 3-1: Template of the individual participant’s data encoding map implementing the TPB model (Ajzen, 2002)

Each of the TPB elements was clearly defined according to the literature, and as a systematic support for data encoding. For each concept or idea mentioned by a given participant, the definitions mentioned on this map would be read and a decision made on its location on the map. For instance, Figure 3-2, gives an illustration of how the behavioral level of the TPB model (Ajzen, 2002) was represented in order to minimize coding bias, by providing a definition of the “behavioral beliefs” and “attitude toward behavioral beliefs” that are easy to read and process. Other TPB concepts were defined in similar manner. A complete illustration of this map is given in the Appendices.
Figure 3-2: Definition of the behavioral level of the TPB model (Ajzen, 2002)

Figure 3-2 indicates that the behavioral level is composed of two components, behavioral beliefs and attitudes towards behavioral beliefs. Behavioral beliefs are beliefs about the likely outcomes of a behavior, and the evaluation of these outcomes in terms of favorable and unfavorable, as applied to scientific inquiry and science fair. The attitude toward the behavioral beliefs is the person’s overall evaluation of performing the given behavior; that evaluation can be favorable or unfavorable as it is applied to scientific inquiry or science fair. Thus, this graphic method of representing the TPB made it easier to compare an idea mentioned by a participant against one component of the TPB to identify where that idea should be categorized.


**Systematic Approach for Coding Actual Interview Data.** For coding the actual interview data, a systematic approach was adopted. First, a map was created for each participant based on the template displayed in Figure 3-1. Then, in reading the interview transcript, ideas related to either scientific inquiry or science fair were identified. The identified idea was then mentally summarized as a “concept or a semantic label” (a set of few words that semantically capture the participant’s ideas with a looser grammatical form). The following step was to define under which “branch” of the map that concept should be placed. When the location was obvious, because of a clear and unambiguous semantic relationship, the mental concept or semantic label was typed directly under the corresponding branch. This was followed by copying and pasting what the participant said as a note that illustrates the created concept, plus several others that tag information: its source (the participant reference number; from 1 to 8), the page number (an Arabic number), and a paragraph number (a capital letter). This precise referencing allowed for specific identification of the source of each concept composing the map. An illustration of this is presented in Figure 3-3.

![Figure 3-3: Illustration of the behavioral level with actual participant data](image-url)
When the final destination (branch) of the newly created concept was not obvious, the definitions of the TPB components given by the map were used to ascertain its final position inside the participant’s map. The final step was to indicate in the file containing extracted participant data that this part of the document was processed and inserted into the map. This was achieved by highlighting the concept (to signify that this concept is relevant), and by striking through it to show that it was incorporated into the map. An example of this is illustrated in Figure 3-4, which is related to the example illustrated in Figure 3-3.

Anne Marie: I think so... Can you explain the scaffolding?

Participant: Scaffolding is the way that you make inquiry more guided or more structured. Scaffolding is the particular supports that I put in place to allow students to access inquiry.

Anne Marie: Do you think that inquiry could be used to scaffold more complex topic for example?

Participant: I think inquiry is one of the best ways to get to higher level of understanding of a topic. I just don’t think you can jump straight to inquiry and have it be very useful.

Anne Marie: Great answers. Our next question. Please comment on the position of your school concerning science inquiry and how this influence your teaching approaches?

Participant: Schools policy, I feel like I’m given a lot of freedom at this school. We are a pilot school so I mean in terms of our schools overall guiding principles for the school and for the science department. We have a Claim Evidence Reasoning focus on teaching so which I think is good because teaching students how to both identify other peoples claims like in text but also generate their own claims about what they have observed is a good scaffold for allowing them to access inquiry because giving them that framework if you give them just a simple graphic organizer what are some things that we observed, this facts that we can write down.

I saw the wave propagate to the left, that’s an observation. That can become evidence later on in something else. Those lists of observations are evidence, we tie them together with reasoning and then we make a claim about what we observed. What is the overall pattern that we see? What is the general theory that we can take from our observations in our evidence? That’s a pretty good structured way inquiry and the

Figure 3-4: Illustration of the actual coding of the participant data

In Figure 3-4, the variation of highlighting color indicates a change of idea expressed by the participant (the choice of the color was random). Part of the text which features the strikethrough but that was not highlighted represents participants’ responses, which were not
relevant to the study. Text in grey represents interviewer’s questions. The capital letter on the left side of the transcript paragraph indicates the paragraph number, as already mentioned. This coding method provided a visual to clearly illustrate what was processed and what was not. The processing of a participant’s transcript was considered complete when all parts of the participant’s speech were crossed out and/or highlighted. Finally, a second judge verified the accuracy of the semantic labels against participants’ original data, its position inside the map, as well as the completeness of the processing of the original participant file in order to further reduce bias.

**Systematic Categorization of All Participant Data.** The fourth step consisted of merging all individual maps into a single map based on the same template mentioned earlier. Once all participants’ data were copied, the data were then categorized in a systematic way by: grouping under the same label concepts, from different participants that have close meaning; grouping labels under a higher level semantic that summarized a set of previously defined labels; and validating the final map obtained to ensure its consistency. An example of such a merging process, related to examples already mentioned earlier, is given in Figure 3-5.

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**Figure 3-5: Illustration of the merging of semantic labels**
This process was applied throughout all findings. A second judge then validated the final map obtained.

**Rigorous Data Analysis and Reporting.** The last stage of data analysis consisted of relating the different findings of each component of the TPB model regarding scientific inquiry and science fair by comparing and contrasting them. The outcomes of this procedure constitute the result section of this study (Chapter 4).

**Validity, Reliability and Triangulation**

Hammersley (1987) asserts that an account is valid if it accurately represents phenomenal features intended to explain, describe or theorize. According to Ritchie and Lewis (2003), the validity of research is conceived as the correctness of the research findings. Internal validity ensures that the researcher conducts an accurate investigation of the subject of investigation, whereas external validity is concerned with the extent to which research findings can be generalized to a larger sample (Creswell, 2013). In this study, sharing drafts of the interview transcripts with each participant to confirm authenticity of their responses ensured internal validity.

Reliability, according to Ritchie and Lewis (2003), is the extent to which research findings can be replicated, if another study is undertaken using the same research methods. Absolute replication of qualitative studies is difficult to achieve since they reflect realities at the time they are collected. However, Creswell (2013) points out that reliability can be enhanced through reflexivity. To enhance reliability in this study, all interviews were recorded to ensure that they provide reliable evidence against which unbiased analyses may be conducted. Additionally, the study was conducted in schools other than the school where the researcher works, and where she has no prior knowledge of teachers’ beliefs and perceptions regarding science inquiry and science fair.
Arksey and Knight (1999) consider triangulation as a strategy used to boost confidence in the research findings. According to Creswell (2012), data triangulation is the process of collecting data over different times using multiple methods. Triangulation helps to reduce personal and methodological biases in an effort to increase the probability of generalizing the findings. Using multiple methods paves way for more credible and dependable information. There exist several different types of triangulation (Denzin and Lincoln, 2011): Methodological triangulation employs the use of multiple methods to collect data; data triangulation entails the use of a variety of data sources to draw conclusions. Investigator triangulation involves multiple researchers investigating a given problem, and theoretical triangulation involves a researcher approaching a study from varied perspectives and hypotheses (Creswell, 2012).

**Conclusion**

A case study is the ideal methodological approach to be adopted when a holistic, in-depth investigation is required, as was the case in investigating science teachers’ behavior for inquiry. Case studies are designed to bring out details from the viewpoint of the participants by employing simple multiple sources of data. Moreover, case studies are multi-perspectival analyses. This research solicited the beliefs of high school science teachers. The beliefs were then conflated to illuminate the teachers’ attitudes for/against science inquiry and science fair projects in the study schools.
Chapter IV: Results

Introduction

This study sought to identify the specific beliefs of science teachers about science inquiry and science fair and how these beliefs affect their implementation of the strategies in their classrooms. The results are as presented in this chapter. The chapter classifies the identified beliefs in the context of TPB (Ajzen, 1991) as either behavioral, normative or control beliefs. The chapter also goes beyond the three basic levels of TPB to highlight science teachers’ behavioral intentions and actual behavioral aspects regarding science inquiry and science fair, as envisaged by the extended TPB (Ajzen, 2002). The identified beliefs were further qualified as either favorable or unfavorable for science inquiry and science fair, respectively.

Behavioral Level

According to Ajzen (2002), the behavioral beliefs comprise human beliefs about the likely outcomes of their behaviors and their evaluation of these outcomes. A positive evaluation would result in favorable beliefs (beliefs that enhance the execution of a particular behavior) whereas a negative evaluation causes unfavorable beliefs about the behavior in question.

The following section describes the findings of this study as it relates to behavioral beliefs and attitude toward behavior as they connect to science inquiry and science fair.

Behavioral Beliefs.

A. Science Inquiry

a. Teachers’ Favorable Behavioral Beliefs

Firstly, this study suggests that science inquiry can have a broad impact on student learning. For instance, science inquiry can improve student performance and learning
experience by leading students to take ownership of their learning --- by helping them to design science fair projects, for example. Thus, inquiry science seems to be also an optimal teaching approach. The broad impact of inquiry on student learning was based on the participants’ views that inquiry can be very beneficial to students (Rosa), is effective and engaging (Nancy) because “[…] students feel invested in discovering things.” This cements Kapucu’s (2014) assertion that the teachers’ beliefs about learning and teaching influence their instructional tendencies within the classroom. A constructionist perspective to teaching, majorly employed in scientific inquiry, will thus entail an environment in which the transmission of knowledge is not restrictive amongst the parties involved.

Secondly, results from participants of this study seemed to suggest that science inquiry improves students’ performance and learning experience. Five out of 8 interviewees believe that inquiry allows the assessment of student's background knowledge, which in turn can help science teachers to scaffold the content (Lili & Rosa), and help students connect learning to life experiences and scientific concepts (Rosa). Secondly, four out eight science teachers believe that inquiry enhances student's cognitive functioning by increasing their retention and expansion of concepts (Lili), leading to a better understanding of the content (Laura). This also enhances students’ ideas (Lili) and allows a significant improvement in students (Lili). As such, this is the best way to get a higher level of understanding (Sanjay), and it is even advantageous for special education students (Rosa). Additionally, half of science teachers expressed strong belief that inquiry generates positive emotional experience, by sparking their curiosity (Sanjay), and is effective in engaging them (Nancy). This is why it is a “[…] wonderful experience for students” (Rosa). Taken together, these three aspects translate to student’s academic success (Lili), and help them to perform better on the standardized tests (Sanjay), and ultimately prepare them for scientific literacy (Sanjay).

A third favorable behavioral belief about inquiry identified in this study is that a
quarter of the respondents believe that science inquiry seems to lead students to take ownership of their learning by, for instance, allowing them to design their own procedure for science fair projects (Laura & Lili). Laura, who believes that by taking ownership of their learning, students take charge over their overall educational development, reiterated these sentiments (Laura). The teacher works towards eliciting students’ knowledge to affirm the different concepts learnt within the classroom. Consequently, the teacher is not only in a suitable position to gauge students’ understanding, but can also determine the quantity and quality of knowledge gathered by students.

By allowing teachers to gauge students’ minds (Rosa), inquiry tends to help teachers adapt a differential learning approach for students (Laura), and implement claim evidence and reasoning to support their learning (Rosa). According to 37.5% of the participants, inquiry is also seen as the optimal teaching approach because it allows teachers to fully implement a student-centered learning approach (Jessica). As Lili stated, inquiry is “[…] the best teaching and learning method” and it should be introduced and supported at a very early stage, as early as at the elementary school level (Rosa).

“…I think that inquiry would be most useful at the elementary level…” (Rosa)

b. Teachers’ Unfavorable Behavioral Beliefs

Despite the favorable behavioral beliefs about inquiry among science teachers, a number of unfavorable beliefs were also identified. Firstly, three teachers believe that inquiry science makes it difficult to establish the required foundation and scaffolding for students’ success. Secondly, three teachers struggle to implement it in certain disciplines, such as in Biology. As Rosa indicated, inquiry is difficult to practice with students undertaking high level conceptual learning that cannot be experienced through activities entailed in the approach (Rosa).

“…it's very difficult to do inquiry with students because they're high-level conceptual
In addition, four teachers believe that inquiry is not always aligned with current test-based educational practices, as it is not always beneficial for standardized test success (Nancy). According to Mike, inquiry does not always prepare students for college (Mike). This implies that scientific inquiry is an additional baggage that the teacher is not fully committed to embracing given the options available and the fear that students will not advance significantly in aspects of science knowledge acquisition.

One other negative behavioral belief exhibited by 37.5% science teachers about inquiry is that the approach requires high cognitive skills from students, as well as students’ capacity to read and comprehend directions (Mike). This calls for students/learners to invoke higher-order thinking skills (Rosa). This is the reason that teachers with a traditional perspective of learning were skeptical about adopting a more student-centered approach within the learning and teaching environment. As Nancy put it, inquiry is difficult if the students were not able to answer open-ended directed tasks (Nancy), which results in students’ fear to take academic risks (Rosa). This school of thought acknowledges that science is best taught when knowledge is transferred to the students from the teachers.

B. Science Fair

a. Teachers’ Favorable Behavioral Beliefs

As for science fair, teachers exhibited four behavioral beliefs that favor its practice with their students. First, two out of the eight participants believe that science fair projects are aligned with the curriculum (Sanjay) and thus hold great intrinsic value for students. This is because inquiry accords students an opportunity to personalize their scientific exploration based on their interests. As Lili stated, “...That is my opportunity to encourage students to enhance their inquiry skills by themselves individually or in teams...”
Secondly, like inquiry science, 25% of science teachers who hold that science fair improves performance and learning experience. This can be attributed to the fact that science fair provides students with an opportunity to enhance their project skills as they are taught to manage projects, present findings, and manage stress related to executing the project (Mike). These are important transferable investigation skills (Jessica) which students may find applicable to other academic and life experiences. Furthermore, about half of teachers contend that science fair generates positive emotional experience for students and boosts their confidence (Nancy), leading to a sense of pride in students (Lili). The feeling of pride/confidence drives students to do better (Nancy). These elements combined help students to be more successful in standardized tests such as the MCAS, as well as improving their scientific literacy as they come to manipulate sophisticated equipment during their practical work (Lili). Students also have the opportunity to work with real scientists (Mike), and especially understand the actual scientific process (Nancy).

Thirdly, as noted with science inquiry, another quarter of teachers in this study indicated that science fair leads students to take ownership of their learning by allowing them to explore personalized topics of interest (Nancy; Laura). These teachers also had the belief that science fair is not necessarily detrimental to Special Education students (Nancy).

Finally, science fair may be combined with science inquiry (Mike) because it enables students to attain the intellectual edge that predisposes them to further deepen their learning. As they advance from the district level, state and even the international science fair competitions, the experience makes the students more competitive. As Lili explained, “...my students that do science fair become very competitive, and they go farther out from the school science fair. They go to the district, they go to the state, and they go to even international competition...”
b. Teachers’ Unfavorable Behavioral Beliefs

On the other hand, the study established three main behavioral beliefs inhibiting adoption of science fair as a learning tool in their schools. First, 50% of teachers do not implement science fair (Jessica) because of the time commitment (Rosa), and because it is regarded negatively by some teachers. Such teachers see science fair as extra work (Lili) requiring them to closely assist students by reviewing their work, and offering advice/guidance in order to elicit the students’ thought pattern.

Second, according to three teachers, science fair is generally ineffective in improving learning, because it has only a small impact on the content learnt (Jessica). This is coupled with science fair, in the view of some teachers, having outdated methods of presentation of project outcome (Mike) such that it does not necessarily help students to become researchers (Rosa). As a result of the ineffectiveness of science fair (Jessica), students are pigeonholed into learning even if it allows them to thoroughly understand the content they have been doing the background research on (Jessica).

A third example of unfavorable aspect of science fair is that it is challenging for some students, such as English Language Learners (ELL) and shy students (Nancy), and it presents mixed outcomes depending upon the student (Nancy). Language is a critical aspect for communicating knowledge and exchanging ideological orientations with colleagues from different schools of thought (Clay, 1998).

It is also imperative to note that one teacher cited limited content knowledge and experience as the major drawbacks against science inquiry implementation. This implies that an informed teacher is more likely to expand the student’s idea by constructively and objectively highlighting issues related to some scientific content.

“...if you're really knowledgeable in any scientific content, then you can widen the students’ idea...” (Lili)
Attitude toward the Behavior.

A. Science Inquiry

a. Teachers’ Favorable Attitude Toward Science Inquiry

In his argument examining the relationship between attitude and behavior, Wicker (1969) concludes that attitude does not predict behavior. Attitude towards behavior is an expression of one’s positive or negative evaluation of undertaking a given behavior. Participants mentioned essentially three main positive outcomes of scientific inquiry in relation to attitude toward behavior. First, three participants described positive attitude toward inquiry, such as liking and enjoying inquiry (Rosa & Jessica), and having strong belief in scientific inquiry (Laura). In addition, participants expressed that science inquiry is a versatile method of teaching since it represents an instrumental component for student understanding (Laura); that it can be differentiated to meet students’ needs; and that it is useful to prepare students to engage in more cognitively demanding task such as Evidence-Based Argumentation (Mike). Another three participants identified scientific inquiry as their preferred teaching method (Jessica, Lili & Pedro), not because inquiry is mandated by the school (Lili) but because it supports inquiry-based teaching (Jessica), and more importantly it is a prerequisite for engaging students in “living science” which will impact science literacy (Sanjay). However, it has been stressed that science inquiry should not be the exclusive teaching model (Pedro), since it should be applied according to the students’ population, needs and experience (Pedro). Therefore, it has been recommended that inquiry should be combined with direct teaching as the “[...] the best teaching method” (Pedro).

b. Teachers’ Unfavorable Attitude Toward Science Inquiry

Notably, 12.5% of participants described science inquiry as unfavorable because it requires more time for students to learn the process as opposed to having students complete a reading assignment and answer questions (Jessica). In addition, they identified science
inquiry as being difficult for teachers to manage because of the time it takes to plan inquiry lessons to expand student knowledge as students manifest different intellectual orientations (Jessica). Furthermore, a quarter of them stated that science inquiry is not adapted for Special Education Students (Mike). As a result of the challenges teachers face to implement it, one participant felt that scientific inquiry is just another, “[…] education fashion” (Mike), and therefore it should not be the only teaching methodology (Pedro).

B. Science Fair

a. Teachers’ Favorable Attitude Toward Science Fair

Half of the participants described favorable attitude for science fair by stating their love (Lili) and strong support for science fair (Jessica, Laura), as a good thing to do once a year (Pedro), and overall as something worth doing especially when students move on to the next level and receive awards (Lili). Thus, science fair has been reported as being appreciated by all teachers (Rosa), even if other participants from different schools stated the opposite. In addition, science fair is seen as beneficial to students because it can be adapted for students with natural curiosity (Rosa), it provides a way to foster student inquiry skills (Lili), and is a good way to encourage students to showcase their learning beyond the school (Rosa); thus, science fair can be a good experience for some students (Rosa).

Another favorable aspect of science fair seems to be that it is a good way to prepare students for scientific careers as they learn the application of scientific method and how to be a scientist (Pedro), but it should not be mandatory (Rosa).

b. Teachers’ Unfavorable Attitude Toward Science Fair

Two participants identified two main unfavorable attitudes for science fair. First, science fair makes inefficient use of class time because it requires students to do the project in class (Mike), and it takes time away from teaching “real” content required for standardized tests (Jessica & Mike).
Second, and opposite to what was mentioned earlier on the Favorable section above, two teachers view science fair as not being relevant to preparing students to become scientists, because it is not realistic as compared to actual research activities (Rosa), and since it does not use modern presentation techniques such as Power Point presentation format for the research presentation (Mike). In addition, science fair is viewed as not being the best way to learn science (Rosa), and it seems to be superficial (Rosa), resulting in the participant questioning of the validity and purpose of science fair (Rosa).

The combined attitudes lead to strong negative feelings against science fair making it not worth the investment (Rosa), and an overall dislike for science fair presentation day. Together, these elements are clearly in contradiction with what other participants have mentioned in the favorable outcome of science fair, and suggest that science fair could result in opposite feelings from teachers.

**Normative Level**

The normative level comprises of normative beliefs and subjective norms. Ajzen (2002) defines normative beliefs as one’s beliefs about others’ expectations and his/her motivation to comply with such expectations; and subjective norms as extrinsic societal pressures that may influence a person to execute a given behavior. In a school setting, societal pressures/expectations may emanate from such stakeholders as parents, teachers, students, the schools and even the state (Kupucu, 2014). These may well play a role in determining teachers’ normative beliefs about particular teaching approaches. The following section describes the findings of normative beliefs and subjective norms as they relate to science inquiry and science fair.
Normative Beliefs.

A. Science Inquiry

a. Teachers’ Favorable Normative Beliefs

This study pointed out that science inquiry is understood as fully open inquiry by some people (Sanjay), usually aligned to school’s goals (Lili) which teachers are expected to meet. One teacher believes that this is beneficial if presented as a complementary approach (Sanjay), requiring a Claim Evidence Reasoning (CER) approach to structure inquiry teaching (Sanjay); therefore, it requires skillful implementation (Sanjay).

Science teachers are also expected to provide an avenue for science inquiry in their classrooms. One approach for advancing inquiry is the use of observations as a critical component of reasoning and entails mining the general theoretical underpinnings from the observations. There is a school of thought that prefers using scaffolding so as to adapt to a more structured scientific inquiry process that allows students to access knowledge. Most teachers adopted these practices because of their strong conviction that such techniques enable abstract content to be absorbed and internalized by students undertaking the particular course. Ajzen contends that such teachers are motivated to comply with expectations and are thus inclined to implement inquiry practices.

Nevertheless, it may not be possible for science teachers to meet all such expectations from others. Notably, the participating science teachers occupy a vantage point from which to identify useful components of scientific inquiry that can be embedded into the teaching discourse. Their practice, in effect, could exhibit beneficial outcomes as students and teachers exercise the liberty to exercise thought patterns.

b. Teachers’ Unfavorable Normative Beliefs

Findings of this study appear to suggest that the meaning of inquiry and its perspectives differed widely among science teachers and depended upon expectations from others, and
especially from the school. One teacher believes that science inquiry is not practical when presented as a mandatory approach, and if starting directly with inquiry approach (Sanjay). This is conflict with teachers’ personal experience and the school’s mandates. As one participant stated,

[...] *I just don’t think you can jump straight to inquiry and have it be very useful...”* (Sanjay).

This divergent view, occasioned by an individual’s extensive professional circumstance, diminishes the value and level of appreciation of scientific inquiry as a mode of transmitting knowledge from teacher to student.

B. Science Fair

a. Teachers’ Favorable Normative Beliefs

If not presented as mandatory, science fair is viewed as favorable (Pedro); other participants also echoed this sentiment.

**Subjective Norms.** As already stated, subjective norms are extrinsic societal pressures that may influence a person to execute a given behavior (Ajzen, 2002).

A. Science Inquiry

a. Teachers’ Favorable Subjective Norms

From this study, it is fair to conclude that science inquiry is beneficial to students because of its intrinsic value for inquiry-based teaching (Nancy), since it is instrumental to students’ understanding (Laura). However, it should not be presented as the exclusive way of teaching (Pedro). Instead, a flexible way to implementing inquiry-based teaching should be encouraged (Jessica). Overall, it improves teaching when a team of teachers works together to construct their own inquiry approach (Sanjay) to implement best practices (Sanjay).
b. School’s Favorable Subjective Norms

Half of the participants expressed strong school support and encouragement for a science inquiry-based teaching model (Nancy & Sanjay) that facilitates self-directed learning by using evidence-based argumentation (Laura); thus, there is strong encouragement from the schools for the implementation of inquiry teaching (Laura & Lili). However, participants also stated that the school is open to other teaching approaches aligned with inquiry (Sanjay), allows flexibility (Sanjay), and does not mandate any particular approach, as already stated (Sanjay).

c. State’s Favorable Subjective Norms

Scientific inquiry supports standardized test taking skills (Laura), since MCAS is perfectly aligned with inquiry-based approach (Jessica) although sometimes the block of time allocated for inquiry may not be sufficient to assess students’ understanding (Laura). About 12.5% of participants reported that standardized tests do not influence the teaching method employed (Pedro). Professional education literature emphatically supports scientific inquiry as the central strategy of science instruction (Minner, Levy, & Century, 2010, p. 474).

d. Teachers’ Unfavorable Subjective Norms

On the other hand, science inquiry is unfavorable because its application depends on the types of students involved (Mike) and requires sufficient teacher content knowledge (Sanjay). The concept holds great appeal for some teachers but they find that concrete application poses a challenge (Mike). Very often, teachers who oppose it are constrained by misconceptions about science inquiry teaching (Sanjay).

e. School’s Unfavorable Subjective Norms

Inquiry science was an initiative at one school in the past but the school does not push it any longer, especially in sub-separate SPED classes. Instead, the school has adopted Evidence Based Argumentation (Mike).
f. State’s Unfavorable Subjective Norms

On the other hand, a quarter of the participants recognized several negative impacts that standardized tests have on inquiry teaching. First, teaching to standardized tests has significant negative impacts on comprehensive teaching. Teachers who have to prepare students for MCAS may risk not having sufficient time to cover all the content needed for the test (Rosa). This makes practice of inquiry more difficult (Rosa). Thus standardized testing has become a source of pressure (Laura), resulting in more demands on teacher time and escalating levels of stress (Rosa); some teachers blame themselves when they cannot meet such demands (Rosa). As a result, standardized tests exert tremendous influence on teaching practices (Rosa), contrary to what was previously alleged by one of the participants.

Secondly, standardized tests elicit strong negative feelings from teachers due to running the risk of diminishing love for learning by students (Rosa), as well as teachers’ love for teaching science (Rosa). As such, standardized testing is viewed as a significant impediment to intrinsic love of science for both students and teachers (Rosa).

B. Science Fair

a. Teachers’ Favorable Subjective Norms

Teachers support science fair participation (Jessica), especially when they receive support from the school (Pedro).

b. School’s Favorable Subjective Norms

Fifty percent of the participants described strong support and encouragement for science fair implementation by school administration (Jessica, Laura, Lili, Pedro). They identified support for supplies and logistics for running the science fair as the main provision they received from school administration (Mike & Pedro).
c. **State’s Favorable Subjective Norms**

Science fair is viewed as being perfectly aligned with MCAS because of the alignment of science fair with the Next Generation Science standards, which will be emphasized on future MCAS tests (Jessica).

d. **Teachers’ Unfavorable Subjective Norms**

There were no unfavorable teacher beliefs for science fair.

e. **School’s Unfavorable Subjective Norms**

One participant perceived pressure from school mandating science fair (Mike).

f. **State’s Unfavorable Subjective Norms**

One participant reported that standardized testing impacts the decision of a school regarding whether or not teachers are permitted to implement science fair (Rosa).

**Control Level**

This level comprises of control beliefs. These are the “beliefs about the presence of factors that may facilitate or impede performance of a behavior and the perceived power of these factors” (Ajzen, 2002, p. 1). This study sought to establish control beliefs of science teachers concerning science inquiry and science fair, which may influence their implementation. The control beliefs and the perceived behavioral control related to science inquiry and science fair are reported in the section below.

**Control beliefs.**

A. **Science Inquiry**

a. **Teachers’ Favorable Control Beliefs**

Participants identified several favorable elements for the control beliefs. First, science inquiry is an effective method that can be utilized as a guiding tool for enhancing the delivery and understanding of science fair projects (Mike), particularly for situations where there is no concrete learning objective and where the overall aim is for learners to familiarize themselves
with the scientific content being introduced (Sanjay), “…Sometimes it's good to let them play around with the concept…” (Sanjay). Scientific inquiry was also considered as an effective approach, and even as a “[…] great teaching method” (Sanjay). Inquiry generates curiosity that enables students to develop their own personal perspective regarding the scientific content they are learning.

Kapucu (2014) emphasizes the availability of teaching resources as a critical factor in the success of the learning process. Science inquiry requires superior teaching skills, which can only be gained through years of experience. This enhances the delivery of scientific content during classroom sessions (Jessica). Experience also develops a teacher’s mastery and control of content knowledge (Jessica), as well as knowledge of teaching pedagogy (Mike). But, science inquiry does not require expertise as a scientist as the subject is dynamic (Mike).

Third, in order to fully benefit students, inquiry science first requires rote knowledge (Sanjay), as this is essential for an in-depth understanding of the scientific content, from the basic to more advanced concepts (Sanjay). Participants reported that students are generally burdened with misconceptions about a vast array of topics, so complementing direct teaching with inquiry will likely resolve misconceptions by relating concepts to their personal experiences (Lili). Participants also argued that scientific inquiry in concert with evidence-based argumentation provides an excellent avenue for analysis and comprehension of content (Mike).

Fourth, science inquiry is especially favorable if applied flexibly, meaning that teachers have the freedom to structure their teaching approach (Sanjay) and adapt it to different teaching situations that would best suit their students (Sanjay).

“…The reason that I came to teach in this school is exactly because I have the freedom to decide when to do what…” (Pedro)
Teachers have the choice of whether or not to apply scientific inquiry (Pedro); therefore, being able to mix different teaching techniques is permissible (Mike), even if it has been mandated that both direct and inquiry approaches are required in order to optimize the learning process (Sanjay).

Facilitating or impeding factors tend to influence the inclination of teachers to adopt best practices when conducting scientific inquiry.

b. Teachers’ Unfavorable Control Beliefs

Ajzen (2002) documents the fact that many teachers cite time as a hindering factor and this belief leads them to conclude that scientific inquiry is impractical to administer. In their view, an unfavorable aspect of inquiry is the time required to implement the process given the intensity of the curriculum as a whole (Nancy & Sanjay) and the fact that the traditional direct teaching method is less challenging to implement (Jessica). The curriculum also does not explicitly identify the optimum approach as the application of scientific inquiry methods.

“...It's definitely harder to do something inquiry-based versus doing something more traditional...” (Jessica).

B. Science Fair

a. Teachers’ Favorable Control Beliefs

One favorable aspect of science fair is the possibility of external support for students in terms of mentoring to enhance the quality of their projects (Laura). Variability in such external support could be responsible for the reported difference in quality of science fair projects students present. As Laura noted,

“...There was clearly a difference in the quality of the projects that were presented...” (Laura)
This was accomplished by the institutional engagement with experts in a given field. The experts helped students with their projects by providing a platform through which the students can conduct their lab work and also interact with resource persons with expertise in a range of disciplines.

b. Teachers’ Unfavorable Control Beliefs

Similar to inquiry-based teaching, time commitment is a real issue and represents the biggest obstacle to science fair implementation (Sanjay).

“…the biggest problem is time. I do not have the time to do that…” (Sanjay)

Science fair can be very time consuming (Mike & Nancy); compounding the problem is the fact that there is limited time available for science fair activity (Nancy), and that science fair conflicts with the time required to meet MCAS objectives (Sanjay). Furthermore, students are not conducting science fair projects independently. Participants also preferred to have an external support to help students develop their science fair projects.

“…like somebody external comes in to do the science fair…” (Sanjay)

The time constraint imposed on science fair implementation creates strong competition with other supports for students (Sanjay); another factor that makes matters worse is that the date for science fair is often not congruent with other teaching commitments (Mike), and its mode of operation is not clearly defined.

Perceived Behavioral Control. Perception, on its narrowed definition is related to organizing, identifying, and interpreting sensory information in order to represent and understand the physical environment surrounding the individual (Schacter, 2011). In its extended definition, perception can be seen as the internal representation of sensory information or past experience (Bonjour, 2016).
Beliefs for Performing Behavior.

A. Science Inquiry

a. Teachers’ Favorable Perceived Behavioral Control

Three participants noted that while they are still able to teach content needed for standardized test (MCAS) (participant3), mastery of content knowledge (Lili & Pedro), and support from school are necessary (Nancy). In addition, a certain level of inborn disposition to teaching is also needed (Pedro).

b. Teachers’ Unfavorable Perceived Behavioral Control

Teaching inquiry is difficult if the teacher’s content knowledge is limited, because content knowledge allows teachers to engage students in more in depth discussion of the content (Lili). Furthermore, when teachers have a mandate to implement a one-size-fits all model, this limits students’ exposure to different styles of learning, which they need to be exposed to (Mike). Moreover, Mike stated that MCAS mandates “handcuff” teachers by restricting their ability to use inquiry-based teaching.

B. Science Fair

a. Teachers’ Favorable Perceived Behavioral Control

Science fair is favorable if teachers decide the types of projects and content (Pedro).

b. Teachers Unfavorable Perceived Behavioral Control

Science fair is difficult to implement due to the lack of teacher knowledge of other science disciplines, is highly demanding because it requires high resources, and time is inadequate in comparison to content covered (Lili). In addition, science fair poses an important stress factor because it is challenging and stressful for teachers and students (Nancy). Therefore, it is impossible to implement science fair for the whole class or school (Rosa). As a result of the above challenges, science fair generated mixed feelings of control among teachers (Nancy).
Perceived Factors.

A. Science Inquiry

a. Teachers’ Favorable Perceived Behavioral Control

The main favorable factor to applying scientific inquiry is some external support, and more specifically, technical support (Lili), and mentoring support provided by external partners (Mike, Nancy, & Rosa). In addition, although standardized testing has been seen as impeding the application of science inquiry, currently it does not prohibit its use for certain topics such as physics (Sanjay). It has been mentioned that the NGSS is more likely to reinforce the use of science inquiry (Nancy).

b. Teachers’ Unfavorable Perceived Behavioral Control

About a quarter of the teachers noted that MCAS is an impediment to the implementation of scientific inquiry, because it focuses on knowledge about facts, and it does not capture scientific skills (Sanjay). In addition, MCAS is actually a threat to inquiry-based learning because it is a source of pressure (Sanjay), due to the fact that it limits the time available for inquiry-based activity (Nancy). Furthermore, MCAS seems to be “[…] killing a lot of inquiry” (Sanjay), and is pushing teachers to abandon inquiry teaching all together (Sanjay).

Additionally, scientific inquiry conflicts with preparing students for the MCAS because it does not seem to be directly suitable for its preparation (Mike), since it puts pressure on students to prepare for the test (Lili). Moreover, MCAS is perceived as being a “handcuff” which does not allow the application of scientific inquiry (Mike).

Finally, scientific inquiry is competing with much more important matter, since teachers’ evaluation is based on the success rate of students on the MCAS (Mike). Also MCAS determines the future of schools, teachers, and students (Sanjay). Therefore, inquiry is seen as less important than achieving high success rate in the MCAS (Nancy).
B. Science Fair

a. Teachers’ Favorable To Teacher Perceived Behavioral Control

The NGSS would encourage the participation in science fair (Nancy).

b. Unfavorable To Teacher Perceived Behavioral Control

Although for some teachers they are required to participate in science fair (Nancy), and since science fair is not actually required to pass the MCAS (Mike), some teachers have decided not to participate in science fair in order to cover MCAS content instead (Mike).

Behavioral Intention

Behavioral intentions are an individual’s expressed behavioral motivations to perform a given behavior for the purpose of achieving some goals. There are three basic parameters that influence one’s behavioral intentions: favorable attitude towards the behavior (Aact); favorable subjective norm (SN), and greater perceived control (Ajzen, 2002). It follows that the stronger the three parameters, the greater one’s intention to perform the said behavior will be. This section reveals science teachers’ behavioral intentions concerning the implementation of science inquiry and science fair.

A. Science Inquiry

a. Favorable Teacher Behavioral Intention

Science inquiry is a goal for the science team in one school (Rosa). Teachers have a desire to help students reflect on diverse scientific concepts. “...We want our kids to be able to use their brains...” (Rosa). Two teachers aspire to expose their students to inquiry activities so as to expand their thinking framework (Rosa); thus, they advocate for science inquiry (Lili). Collaboratively, teachers have always utilized inquiry as the key component to ensure that students acquire necessary scientific skills. This they achieve through a well-coordinated series of activities and lab work that expose their students to scientific discourse. “...we have always used inquiry as our goal...” (Rosa).
b. Unfavorable Teacher Behavioral Intention

Teachers did not report unfavorable behavioral intention for science inquiry.

B. Science Fair

a. Favorable Teacher Behavioral Intention

Participant mentioned several elements favorable to science fair. One participant stated that science fair is potentially an awesome strategy due to the nature of activities it presents (Sanjay): “[…]. A well designed inquiry activity can really convince them of the scientific principles...” (Nancy).

Motivation is a key component that sustains the urge of both students and science teachers to proceed with science fairs. Participants expressed their intent to continue science fair in the future despite school requirements by preparing for it throughout the year (Nancy).

“…This shouldn't be a once a year thing. It should be something that we practice for throughout the year…” (Nancy)

Another participant advocated for science fair but was hesitant due to limited resources (Lili). This participant expressed her intention to incorporate inquiry into her teaching, but felt constrained by limited resources in her school.

“[…] however every school has limited resources…”

The study noted that the overriding goal of teachers was to advocate for the adoption of scientific inquiry as an essential component of teaching and learning. The semblance of excitement occasioned by its potential adoption in the school was worth mentioning. “[…] everybody is on board with it” (Sanjay).

b. Unfavorable Teacher Behavioral Intention

The main unfavorable aspect of science fair is the need to maintain a balance between inquiry-based and other learning styles that each student brings, as each style has its strengths and limitations (Nancy). This is due to the fact that different learning styles work best with
Actual Behavior

Ajzen (2002) associates actual behavior with real human actions, which are determined by one’s behavioral control. According to Ajzen, actual behavior is closely determined by one’s actual behavioral control. Actual human action may be conceptualized as the sufficient degree of actual control one has over himself when opportunity presents itself to perform a given behavior. This is determined by four fundamental environmental factors summarized as TACT namely, target, action, context and time (Ajzen, 2002). In other words, given favorable target, action, context and time to execute a given behavior, an individual may or may not perform the behavior depending on his/her level of actual control over the behavior. This study seems to reveal various actual behaviors of science teachers concerning the implementation of science inquiry and science fair, as reported in the section that follows.

A. Science Inquiry

a. Favorable Actual Teacher Behavior

This study unveiled a wide range of science teachers’ actions in the classroom that are favorable to scientific inquiry. Firstly, although most teachers are implementing inquiry-based teaching and learning (Jessica, Laura, Lili), a certain level of teaching flexibility is maintained by implementing a “student-centered procedure” approach to learning. This approach, the study noted, involved the students conducting the majority of the activities comprised in the learning process, thus enabling them to explore and understand novel concepts within the scientific field. As one participant stated, 

“I would say the perfect science teaching and learning approach would be one that is very student-centered, where students are doing most of the work, they're doing most of the exploration...” (Laura).
This attitude can be pegged to the teacher’s pedagogical experience and beliefs in scientific inquiry, as these will have an impact on the students’ learning experience.

Secondly, a quarter of the participants alluded to a direct teaching approach followed by inquiry learning for certain topics (Rosa). This can be viewed as a sliding scale approach to inquiry, which ranges from a scaffolded approach to a completely open inquiry (Sanjay). Scaffolding content for students refers to a way in which content is hidden so that students are able to acquaint themselves with different perspectives (Bature & Jibrin, 2015). The study noted that teachers singled out this method as being particularly efficient for teaching complex scientific concepts. As one participant stated,

“…I could definitely see myself doing some, using inquiry to scaffold photosynthesis. It would be a very basic level and being able to refer them back to questions that may come up from the inquiry activity that they've done…” (Rosa).

Scaffolding has widely been recognized as a useful inquiry tool in the classroom. In a study to characterize pre-service teachers’ perceptions of scaffolding as a tool for improving Mathematics teaching, Bature and Jibrin (2015) established that the teachers strongly praised this strategy for improving their practice through increased classroom participation. Similarly, Makar, Bakker and Ben-Zvi (2015), identified scaffolding as a norm for developing argumentation-based inquiry in elementary mathematics classrooms. Additionally, Lin (2014) documented that teachers in a content and language integrated school also encouraged scaffolding to enhance students’ participation. According to Janneke et al. (2013), scaffolding has also been recognized for its role in improving student’s independent and contingency working in the classroom; which enhances their personal appreciation of the content. Allowing students to explore different scientific concepts on their own before the teacher explains them, the study noted, has yielded significant improvements.
The study also revealed that science teachers favored the use of inquiry to connect students’ learning to real life experiences to link their basic scientific knowledge to abstract concepts. As one teacher mentioned, “...I always try to introduce it with something that the kids know or might be familiar with, or something that might be happening in the news...” (Rosa).

Teachers with more experience implementing inquiry are encouraging novice teachers to implement the approach in their teaching. This is very instrumental in turning their attitude towards scientific inquiry (Lili). Thus, teacher’s behavior can be influenced by favorable external factors that are likely to motivate them to achieve their goals. The teacher’s content knowledge also impacts his or her use of inquiry, as it affords room for the teacher to be more engaged and creative (Stevens & Wenner, 1996; Vaidya, 1993). The study noted that scientific inquiry is the backbone of lessons taught in class. Evidently, students tend to understand key concepts better and make lasting connections, as they are practically and actively involved in knowledge acquisition. And this, in the long run, enhances the ideological orientation of the students.

b. Teachers’ Unfavorable Actual Behavior

Results of this study also seem to indicate that the implementation of scientific inquiry is more related to specific topics (Mike). The findings also indicate that “mundane aspects” are more clearly communicated and easily understood by practicing, in an almost mechanistic way, basic activities related to the concept being taught (Laura). Inquiry is also based on student population and their specific needs. For instance, specialized education, notably, is individualized and adapted to student learning needs within the context of this study. Regarding the school’s policy concerning inquiry-based learning, the study noted that this, too, might influence methods employed in the transfer of knowledge between teacher and student, as was emphatically pointed out by Mike. “...We moved away from that. Like I
said before, the new push in our school is Evidence-Based Argumentation which does require some inquiry...” Mike added.

B. Science Fair

a. Teachers’ Favorable Actual Behavior

Science fair is very popular among teachers, even among those new to science fair (Nancy). Five teachers have organized several science fair projects in the past (Jessica, Laura, Lili, Mike, Pedro), and three of them have taken part in science fairs for most of their careers. In addition, most teachers tend to adopt a student-centered approach to science fair by first encouraging students to participate (Lili), selecting the most suitable students for this type of project (Jessica), providing them with example and templates (Nancy), sending them to external inquiry labs to conduct their project (Rosa), adapting the curriculum to better suit science fair requirements (Nancy), and scaffolding science fair projects for newcomers (Pedro). Moreover, teachers who have experience participating in science fair provide additional support to novice teachers, first by encouraging them to take part in the process (Lili), and also by helping them to organize science fairs (Lili). Science fair projects are more engaging and ensure that students are not only engrossed throughout the semester but also predisposed to aspects within the scientific field. Partnership support for the students cemented their zeal and behavior towards participating in scientific fairs.

“...I think science fair is a good way, first, to learn to apply the scientific method, and second, it's also a good way to encourage students to show what they've learned and not just at the school level but also at city level and higher. I think science fair once a year is a good thing to do...” (Pedro).
b. Teachers’ Unfavorable Actual Behavior

Due to demands on their time, two teachers in this study indicated that they no longer participate in science fair (Mike), and one has *never* taken part in science fairs prior to the current school year (Pedro). The study noted that this pattern of behavior was evident despite teacher’s acknowledging the link between scientific inquiry and science fair. According to Jessica, students tend to take more time figuring out the different ways of linking knowledge to their science fair projects. As Jessica stated,

“…*our biggest complaint as a team is that it takes a lot of time out of the actual content that we're teaching although it does tie into it when we are doing these labs...*”

The attitudinal tendencies towards science fair projects were also seen to vary for different schools and teachers, and adopting a standardized approach to measure science fair implementation is not viable. Mike asserts that a teacher’s teaching style and the students’ attitude toward the learning activity will, to a greater extent, determine the behavior and approach a teacher is to adopt in delivering the content. He further claims that students need to be exposed to different teaching and learning styles to enable them to be in sync with the industry.

This study also revealed that state mandated tests, curriculum and accountability requirements are over-emphasized at the expense of inquiry and science fair, and that a teacher’s performance is evaluated based on his/her students’ success on state mandated tests. As stated by one of the participants,

“[…] I get evaluated on how many of my students pass the MCAS so it's high stakes for me too. I don't get hired or fired according to that, but, yeah, the administration looks at how many of my students pass the MCAS. It's high stakes for me too which personalizes it, and that's not okay when we're talking about a state mandated test.” (Mike)
Chapter V: Discussion

Introduction

This chapter presents a critical discussion of the findings of this study. In order to do so, the chapter begins with a brief overview of the research context, followed by a summary overview of the methodology used to arrive at the findings. There follows a discussion of the main results of the study and implications for practice and research. The chapter also highlights the inherent limitations of the study before stating the main conclusion and recommendations arising from the findings.

Research Context

This section provides a summary of the background research and research gap, as well as a restatement of the research question and hypothesis.

Summary of Background Research. For more than three decades, professional literature from the field of science education has documented the important role of scientific inquiry strategies, such as science fairs, Olympiads and projects, in increasing achievement and improving students’ retention of science concepts (Minner, Levy, & Century, 2010, p. 474). In the 18th and 19th Centuries, scholars noted the significance of experiential learning, direct observational studies, object teaching, activity instruction and child-centered learning as described in the historical works of The Committee of Ten, John Dewey, and McMurray, among others (Haury & Rillero, p. 18-20). Similarly, the National Science Education Standards (NSES) recognized that “inquiry into authentic questions generated from student experiences should be the central strategy for teaching science” (Trautmann, MaKinster & Avery, 2004, p. 1), a position that is also held by the Next Generation Science Standards, NGSS (NRC, 2013).

Today, although inquiry-based learning is central to science education reform, the majority of science classrooms have students who continuously receive “parcels of pre-
packaged knowledge from their teachers through direct transmission and/or carefully orchestrated learning activities” (Sadler, T. et al., 2009, p. 235). For decades, the scientific and educational communities have agreed that science should be taught using the inquiry model. Engaging students in authentic open-ended inquiry requires a teacher to acquire effective strategies, confidence, an understanding of real life application of science, scientific research experience, and a sound grasp of the knowledge of inquiry. As Hoang (2010) explained, “until teachers themselves develop competency at conducting science inquiry investigation, analyzing and graphing data, and constructing claims in a canonical fashion, there will be little opportunity for their students to participate in projects which allow them to gain clear competency at those practices” (p. 636). Consequently, teacher preparation programs, as well as teacher professional development, must provide opportunities for teachers to construct their own knowledge and understanding of effective instructional practices. They must also allow teachers to develop their own theories of inquiry teaching and learning by providing them with research field experiences. These experiences foster collaboration with scientists who can support teachers with lesson modification and lab activities to include more authentic inquiry. For instance, Dresner and Worley (2006) reported that teachers’ participation in ecology research experiences strengthen their confidence in conducting biology projects with their students, and contributed to significant changes in their classroom practices. Participants also reported that the collaboration with scientists influenced them to continue to address science education reform initiatives (p. 7).

Additionally, teacher education programs and professional development must also include teaching strategies that assist teachers in not only acquiring the skills necessary for inquiry, but also for overcoming obstacles to effective inquiry science instruction (Hughes, 2005). Professional development activities that elucidate the numerous challenges of implementing inquiry-based science are necessary to better support teachers to engage
students in inquiry of abstract science concepts (Judson, 2006). Furthermore, teacher education programs and teacher professional development programs that increase self-efficacy, lower teacher/student anxiety, and increase teacher effectiveness are also essential components in furthering the goals of science education—to educate scientifically literate citizens to meet the innovative and challenging scientific needs of the 21st century (Hughes, 2005). The implementation of scientific research as part of teacher education programs—and specifically science fair projects—is, therefore, key to achieving these needs.

Research Gap. As much as the subject of inquiry has dominated recent scientific discourses, so has it been a revolving theme in pedagogic research. A wide range of investigative efforts has focused on the value of science inquiry as a cornerstone of science teaching (Brunsel, 2010). Both in the US and abroad, scholars have continually investigated the impact of inquiry-based science instruction on various aspects of science learning. For instance, Geier et al., (2008) sought to explore how science inquiry affects the achievement of historically underserved students on standardized tests. Lewis and Lewis (2008) also sought to find out whether the inquiry-based science instruction approach could help bridge the inequalities previously reported in learning achievements of college students. While in Australia, scholars have investigated the impact of inquiry science instruction on the short-term motivation of 14-15 year old science learners, with a goal of improving science learning among them. US researchers have invested efforts into exploring knowledge acquisition among elementary level (kindergarten) science learners (Palmer, 2009; Patrick et al., 2009; Minner, Levy & Century, 2009). All of these studies, and many more, have presented inquiry science as an optimal approach that enhances student learning and associated achievement, a recommendation which has informed the positive view of science inquiry, and its endorsement thereof among science professional bodies, as a central strategy in science teaching.
However, as already stated, the US remains far from the goal of embracing inquiry science as a norm in classrooms, and efforts to attain this objective are obstructed by significant challenges. This study contends that while research literature has tried to explain the positive influence of science inquiry on science learning, little has been done to put into context factors affecting teachers’ actual adoption and implementation of inquiry-based science instruction approaches. Only a limited amount of literature exists relating to this subject. For example, Bryan (2003) and Forbes et al., (2013) studied how inquiry science and science fair are implemented by science teachers at elementary and middle school levels. However, there is still a great deal to learn regarding scientific inquiry in secondary school classrooms, since it remains unclear whether or not the instructional strategies and curriculum driving scientific inquiry at elementary and middle school levels apply to teaching inquiry-based science in high school.

Furthermore, while there is also some research relating the implementation of science inquiry to teachers’ experience, content knowledge and training (Stevens & Wenner, 1996, Prawat, 1992, etc.); little is known about the behavioral aspects of science teachers, which are likely to impact their use of inquiry-based practices. As such, this study adopted a human behavioral approach to illuminate factors (behavioral factors – beliefs) influencing implementation of inquiry-based science practices, including science fair, in American high school classrooms.

**Research Question.** How do teachers’ beliefs, about science inquiry and science fair affect their implementation of science inquiry in their teaching, and in particular their use of science fair projects?

**Research Hypotheses.** Teachers’ use of inquiry is a human behavior that can be explained (at least understood) using human behavioral beliefs theories.
2. Science teachers’ beliefs (behavioral, normative and control beliefs) about science inquiry are predictive of their implementation of such strategies in the classroom/school.

3. Science teachers' beliefs about science fair are predictive of teachers’ participation in science fair.

**Summary of the Methodology**

A case study approach was adopted to answer the research questions. Data was collected by means of semi-structured interviews, which were administered to a randomly selected sample of eight (8) science teachers across three high schools in Boston. The main criteria for sampling participants were the length of their teaching experience (at least 3 years), their willingness to take part in the study, and their teaching of various science subjects. The resulting participants comprised teachers who have worked in Boston Public Schools between four and fifteen years, in either the same school or up to four different schools. One interview was conducted with each participant at his/her school after school hours. Each interview lasted about one hour and was conducted over a period of two weeks. The interviews were recorded, transcribed, and analyzed to extract emerging themes related to teachers’ beliefs about inquiry and science fair projects.

An original approach to data analysis was developed that essentially implements Ajzen’s TPB model (2002). This approach gives a visual template representation of the exact and detailed description of the six components of the TPB: the behavioral, normative and control levels, followed by the behavioral intention, actual behavior and finally actual control. This graphical representation was used as a systematic support for data encoding to minimize coding bias.

First, for coding the actual interview data, a systematic approach was adopted, which was initiated by first creating a visual map for each participant based on the template
described previously. Then, in reading the interview transcripts, the ideas related to either scientific inquiry or science fair were identified. The identified concepts were then mentally summarized as a “concept or a semantic label” (a set of few words that semantically capture the participant’s ideas with a looser grammatical form), and placed in the right place in the participant’s map; the processed concept was represented in a branch, and what the participant actually said as a note that illustrates the created concept, plus several tagging information: its source (the participant reference number; from 1 to 8), the page number (an Arabic number), and a paragraph number (a capital letter). As already mentioned, this exact referencing allowed for precise identification of the source of each concept composing the map. The last step of the encoding process was to indicate in the file containing the extracted participant data that the part of the document related to the concept currently dealt with, was processed and inserted into the map. This was achieved by highlighting the idea (to mean that this idea is relevant), and by striking through it to show that it was incorporated into the map. In order to further reduce encoding bias, a second judge verified the accuracy of the semantic labels against participants’ original data, its position inside the map, as well as the completeness of the processing of the original participant file in order to further reduce bias. Then, a systematic categorization of all participant data was conducted by merging all individual maps into a single map that was based on the same template mentioned earlier. All participants’ data were copied, and then categorized in a systematic way by: grouping under the same label ideas, from different participants, that were the same or very close; grouping labels under a higher level semantic that summarized a set of previously defined labels; and validating the final map obtained by a second judge to insure its consistency.
Finally, a rigorous data analysis and data reporting was carried out. Comparing and contrasting the different findings for each component of the TPB model, regarding scientific inquiry and science fair, achieved this. The outcomes of this procedure constituted the result section of this study summarized in the main findings section below.

**Main Findings**

From the results of this study (Chapter 4), this section takes stock of the main findings and briefly analyzes them with a more global perspective. In doing so, the TPB model (Ajzen, 2002) was used to infer the actual behaviors of teachers in the implementation of scientific inquiry from the very first steps through its successive components. The same approach was also taken regarding the findings about science fair. Lastly, the section takes a global look at how findings of scientific inquiry relate to those of science fair.

**Scientific Inquiry.** As Ajzen’s (2002) TPB model suggests that the first three levels of human beliefs (behavioral, normative and control beliefs) interact to give rise to behavioral intentions. Behavioral intentions, in turn, define one’s actual behavior or actual control over a given behavior. This study established various favorable and unfavorable beliefs about science inquiry among the participants. These were identified as behavioral, normative or control beliefs. This chapter aims illuminate how science teachers’ favorable/unfavorable behavioral, normative and control beliefs interact to define their behavioral intentions regarding scientific inquiry. This will ultimately lead to the understanding of the actual favorable/unfavorable behaviors of teachers toward science inquiry.
**Behavioral Level.** This level defines human beliefs about the likely outcomes of their behaviors and their evaluation of these outcomes Ajzen (2002). A positive evaluation would result in favorable beliefs whereas negative evaluation causes unfavorable beliefs about the behavior in question.

a. **Favorable Inference**

The findings indicate that science teachers had various behavioral beliefs about science inquiry that motivated their implementation of the approach. Most notably, the belief that teachers have about the improvement they can see on the students’ performance and learning experience made them appreciate inquiry as the best teaching approach. Additionally, seeing students take ownership of their learning was seen to translate into a belief that inquiry is the optimum teaching approach. Since we know that behavioral beliefs determine the attitude toward behavioral beliefs (Ajzen, 2002), this suggests that these favorable behavioral beliefs determine the positive attitude that teachers have expressed toward inquiry, leading them to naturally choose inquiry as their preferred teaching method.

b. **Unfavorable Inference**

Likewise, unfavorable behavioral beliefs were also identified among teachers. Some teachers believed that inquiry science is not aligned with current test-based education, and requires high cognitive skills from students. Going by the same definition of behavioral beliefs (Ajzen, 2002), it follows that these negative beliefs may be responsible for the unfavorable attitudes expressed, such as that science inquiry is not adapted to special education students, and should not be the only methodology. Consequently, the findings suggest, inquiry science is viewed as yet another reform not embraced by teachers.
c. Overall Inference

Overall, the findings of this study reveal that science teachers would naturally choose inquiry if they believe that inquiry boosts students’ learning, and consequently enhances their performance. However, if inquiry is prescribed to them as a mandatory methodology for teaching, they tend to see it as yet another ineffective education reform, and they tend to push back.

**Normative Level.** The normative level comprises human beliefs about others’ expectations and one’s motivation to comply with such expectations (Ajzen, 2002). These expectations determine the subjective norms that influence a person to behave in a certain manner – societal expectations and pressures. Whether or not one is motivated to comply with these extrinsic expectations enhances or impedes their execution of a behavior (Godin, 1996).

a. Favorable Inference

From the above summary of the definition of normative beliefs, the findings suggest that some teachers believe that science inquiry is usually aligned to the school’s goals, which teachers are expected to meet. Others believe that inquiry is beneficial if presented as complementary approach coupled with Claim Evidence Reasoning (CER) strategies in order to structure inquiry teaching; this is the reason they believe that science inquiry requires skillful implementation. Since it has been established that normative beliefs determine subjective norms (Ajzen, 2002), this can be used to explain the relationship between the normative beliefs and subjective norms found in the sample. In fact, the findings indicate that, since teachers believe that science inquiry is beneficial for students if presented as a complementary learning approach (normative belief), it is therefore logical for them to use it
to improve their teaching, as long as science inquiry is not presented as a dogma (subjective norm). Therefore, since schools are currently advocating vociferously for science inquiry, they should remain open to other approaches, especially because MCAS is seen by some teachers as perfectly aligned with inquiry-based teaching, and therefore does not have a strong influence on teaching methods adopted by teachers.

b. Unfavorable Inference

Once again, the results of this study seem to suggest that most teachers believed that science inquiry is not practical when presented as a mandatory approach and if commencing directly with inquiry approach. From Ajzen’s TPB model (2002), unfavorable normative beliefs – like favorable beliefs – determine subjective norms. As such, these beliefs may explain the misconceptions related to scientific inquiry held by most science teachers, especially the fact that some have reported that the application of inquiry requires depth of content knowledge. These unfavorable beliefs might also explain why teachers believe that the use of inquiry should depend on the ‘type’ of students, and therefore they tend to think that, although the concept of inquiry appeals to them, they find it not practical or applicable. This, in turn, may explain why some schools no longer mandate inquiry as a teaching method, and view teachers as having strong negative feelings about MCAS that they view as further negative factors impacting the implement of inquiry-based teaching.

c. Overall Inference

Overall, the findings suggest, from the lens of Ajzen’s TPB model (2002), that as long as teachers do not see inquiry as being imposed upon them, they find it beneficial for their students and tend to actually implement it in their teaching. In return, their attitudes resonate in a positive and constructive way with the school’s goals about implementing inquiry-based
teaching. However, as soon as inquiry is seen as mandatory or as dogma, the findings suggest that this forces teachers to, first, disassociate from inquiry, and then develop a strong aversion to it, and finally develop an abiding opposition to it. Ultimately, this may lead the school into complete abandonment of the implementation of inquiry-based teaching altogether because of teachers’ pushbacks.

**Control Level.** According to Ajzen (2002), the control level constitutes control beliefs, which he defines as ones’ beliefs regarding the existence of factors influencing behavior, and the perceived power of such factors. These factors may enhance (favorable) or impede (unfavorable) the execution of a particular behavior, also known as perceived behavioral control.

**a. Favorable Inference**

Two contrasting schools of thought emerged from this study regarding science teachers’ favorable control beliefs for scientific inquiry. On one hand, findings document the fact that teachers believe that inquiry-teaching methods require good teaching skills to fully benefit students, especially if flexibility in its implementation exists. Since we know that control beliefs determine perceived behavioral control (Ajzen, 2002), as a result, these favorable beliefs suggest that the positive perceived beliefs that teachers have about their ability to teach the content required for MCAS success using inquiry depends upon how much control they anticipate having over applying inquiry (the idea of flexibility mentioned above). On the other hand, the study indicate that science teachers’ capability to implement inquiry seems also to depend on their content knowledge, a certain level of inherent disposition to teaching, as well as support from the school. In this way, our findings suggest that the current standards do not stop them from applying inquiry, even though they would be
more likely to implement the new NGSS standards.

b. Unfavorable Inference

On this end, this study contends that some teachers believe that the time required to implement inquiry-teaching methods, coupled with the belief that inquiry-based teaching is harder, is excessive. Invoking again Ajzen’s TBP model (2002), these seem to determine the unfavorable perceived beliefs that inquiry is not possible if the teacher has limited content knowledge, and especially that inquiry is inefficient when implemented as a “prescription-based teaching.” In such cases, the findings suggest that there is a high risk for inquiry to be seen as competing with “more important matters”, such as preparing students for the MCAS, which would in turn become a threat to inquiry-based teaching, and thus lead teachers to feel that MCAS is a ‘handcuff’ that does not allow full implementation of the inquiry model.

c. Overall Inference

Taken together, the findings from this research suggest that from the teachers’ perspectives, inquiry-based teaching requires specific skills such as depth of content knowledge combined with some inherent teaching skills. However, those do not determine the actual implementation of inquiry by teachers. In fact, the finding points strongly toward the level of control over which teachers seem to have regarding applying inquiry; it is that level of perceived control that would ultimately determine the actual likelihood of its practical implementation. Thus, the implementation of inquiry depends on skills that can be instilled, and freedom that needs to be given to teachers.
Behavioral Intention. The TPB model proposes that outcomes at the behavioral, normative and control levels are combined together to determine/explain the person’s behavioral intentions (Ajzen, 2002). The findings from these three different levels, when combined, undoubtedly support this vision. Because teachers would naturally choose inquiry as their teaching method (behavioral level), that their attitude resonates constructively with that of the school policy in relation to the implementation of inquiry-based teaching (normative level), and the findings that the actual implementation of inquiry requires teachers to have depth of content knowledge as well as inherent teaching skills (control level), it clearly appears that those findings could be used to explain the reason teachers have the desire to increase students’ scientific knowledge by exposing them to inquiry activities. By so doing science teachers seek to increase their students’ critical thinking ability; thus inducing teachers to advocate for science inquiry processes and establish inquiry-based teaching as the goal for the science team in schools. Ultimately, teachers want to work constructively with the leadership team to implement inquiry-based teaching school-wide.

However, these behavioral intentions exist only when teachers feel that inquiry is not imposed on them as the only methodology for science teaching. In such a case, there would be a real risk of teachers seeing inquiry as yet another ineffective education reform, which they would not embrace. This would make them disassociate themselves from it, developing strong resentment against it, eradicating their natural aspirations to teach it and ultimately leading to fierce opposition to implementing it. Undoubtedly, such a situation would certainly have disastrous consequences on the school leadership team in their ability to implement inquiry-based teaching at the whole school level.
**Actual Behavior.** According to the TPB model (Ajzen, 2002), actual favorable behaviors depend essentially on favorable behavioral intentions, and, similarly, actual unfavorable behaviors depend essentially on unfavorable behavioral intentions. For this study, when teachers are permitted a certain level of teaching flexibility, in particular as it relates to when to apply a particular strategy, most will implement an inquiry-based teaching and learning with their students. They also encourage and support new teachers to do the same. However, when inquiry is imposed on teachers, they first start to apply it only for specific topics, and then gradually stop using it as their resentments against the imposition increases, causing the school to abandon implementation of an inquiry-based teaching because of teachers’ resistance.

**Science Fair.** In relation to science fair inquiry, based on the TPB model (Ajzen 2002) and the analysis carried out for scientific inquiry, this section now seeks to demonstrate how the favorable/unfavorable findings at the behavioral, normative and control levels interact to shed some light on understanding the favorable/unfavorable behavioral intentions that ultimately result in understanding the actual favorable/unfavorable behaviors of science teachers toward science fair as a form of inquiry.

**Behavioral Level.**

a. **Favorable Inference**

According to this study, teachers who have a preference for science fair as a form of inquiry generally believe that science fair has intrinsic value for students, because it improves their performance and learning experience, while coincidentally allowing them to take ownership of their learning as they explore science topics of interest. In addition, science fair offers the added value of being aligned with the curriculum and can be combined with
inquiry to deepen students’ critical thinking skills beyond the science classroom. Since we know that behavioral beliefs determine attitude towards behavior (Ajzen, 1991), these favorable beliefs determine teachers’ positive attitude toward science fair because naturally, it appears to be beneficial for students, and can potentially prepare them for a science career.

b. **Unfavorable Inference**

On the other hand, some teachers (and/or schools) do not employ science fair as a form of inquiry since, according to the findings of this study, they believe that science fair is a challenging academic undertaking for some students and, overall, an ineffective method for improving science learning. As we already know from Ajzen’s TPB model, behavioral beliefs determine attitude towards behavior. Thus, the results of this study clearly indicate that these unfavorable beliefs lead to strong negative feelings about science fair because it is seen as an inefficient use of instructional time, and is especially irrelevant to preparing students for a career in science as well as for standardized tests.

c. **Overall Inference**

It is clear from these findings that there is a divide amongst teachers about the value of science fair as tool for improving science learning. While others feels it is beneficial in preparing students for a scientific career, a host of others believe that it is an ineffective learning tool that does not prepare students for a science career or standardized tests. This difference of opinion demonstrates that the implementation of science fair largely requires teachers’ buy-in, since their negative attitude would jeopardize any effort toward its implementation by teachers and schools.
Normative Level.

a. Favorable Inference

Analysis of science teachers’ normative beliefs revealed interesting twists about extrinsic factors influencing their perception of science fair as a useful inquiry tool. Teachers alluded to the point that when science fair is not mandatory, they tend to embrace it and engage their students in science fair projects. In fact, they even support and encourage other teachers to undertake science fair with their students. This is especially more evident in environments where schools provide material support for science fair. In this case, they see that science fair aligns perfectly with mandated tests like MCAS, and even comply with strong enthusiasm for its implementation by the school.

b. Unfavorable Inference

Teachers indicated that as soon as science fair is presented as mandatory by the school leadership team, they develop strong negative feelings toward supporting science fair projects. Most of them then begin to argue about the time commitment necessary to run it, the lack of alignment to mandated tests such as the MCAS, and finally that it is not an efficient way of teaching and learning. The ultimate consequence is that science fair ceases to be an accepted practice in the school.

c. Overall Inference

Overall, normative beliefs play a critical role in shaping science teachers’ preference for science fair as a useful form of inquiry. Given the flexibility and relevant support, the study suggests, teachers embrace science fair as an important inquiry tool whereas when imposed as a mandatory practice by the school, teachers tend to resent its implementation and refute it as an ineffective approach. This raises many questions regarding whether these are justifiable claims or merely excuses to avoid mandated science fair.
**Control Level.**

a. **Favorable Inference**

At the control level, the study sought to explore the existence of extrinsic factors that influence teachers’ use of science inquiry, and the perceived power of such factors (Ajzen, 1991). The study implies that when mentoring opportunities exist for students from external partners, teachers are more likely to run a science fair. Teachers also exhibited a great desire to be given the full discretion and complete control of the types of projects in which they are interested and feel more comfortable supporting students with.

b. **Unfavorable Inference**

On the other hand, the time commitment to support students in developing and completing their science fair projects can be quite significant, and therefore interfere with other teaching responsibilities. This situation can lead teachers to develop negative feelings about science fair by perceiving it to be a significant stress factor. This is especially the case since science fair is not required to pass the MCAS tests, encouraging teachers not to participate in order to cover MCAS content in more depth to insure the success of more students on the test.

c. **Overall Inference**

In sum, the study indicates that teachers who received external support for their students to participate in science fairs tend to have a positive view of science fair. However, time constraint was seen as the greatest factor eroding teachers’ preference for science fair, especially since it is not a prerequisite for their students to pass mandated tests.
**Behavioral Intention.** As mentioned earlier in the section above on inquiry-based teaching, the TPB model proposes that the outcomes at the behavioral, normative and control levels are combined together to determine/explain a person’s behavioral intentions (Ajzen, 2002). Concerning science fair, when we combine the findings from the three different levels, the study suggests that science fair can be recognized as a potentially outstanding learning activity in which nearly every teacher would love to participate. This especially applies if it is a yearlong activity and would thus minimize conflicts with teaching MCAS content. Under these circumstances, teachers would advocate for science fair to their peers. Then again, when science fair is imposed on teachers, there is a high risk of them developing an aversion to science fair. This would create an obstacle to widespread participation and constitute interference with teaching MCAS content.

**Actual Behavior.** Using again the TPB model (Ajzen, 2002), we know that the actual favorable behaviors depend essentially on favorable behavioral intentions. Similarly, the actual unfavorable behaviors depend essentially on unfavorable behavioral intentions. Applying this principle to science fair, findings indicate that teachers who have positive behavioral intentions toward science inquiry are more likely to effectively expose their students to science fair, since science fair was found to be very popular amongst teachers who indicated that they prefer science inquiry. Such teachers usually tend to adopt a student-centered-approach to science fair and are very keen to support other teachers, especially teachers new to science fair, to conduct science fair projects with their students.

On the other hand, from the participants’ view, it could be concluded that science teachers who developed an aversion to science fair are much less actively involved, or naturally do not take part altogether. This can result, in some cases, in an entire school not participating in science fair. The net effect is that students are deprived of the opportunity to
explore, apply or deepen science content learned in class through an independent research project.

**Relationship between Scientific Inquiry and Science Fair.** This study was initially based on the presumption that science fair is an effective opportunity for teachers to engage students in scientific inquiry. Since scientific inquiry and science fair are closely linked, one can reasonably expect a high correlation between them. In other words, the study expected that when teachers implement an inquiry-based teaching approach, they are more likely to participate and engage their students in science fair projects. These initial expectations are clearly justified by the findings of this study.

This study implies that, science teachers who implement inquiry, essentially because they have been given a certain level of teaching flexibility to be able to choose when and what it is used for, are also those who are most often actively involved in engaging their students in science fair projects, as well as often helping colleagues to implement science fair projects in their work. On the other hand, teachers who do not employ inquiry, essentially because it has been imposed upon them, the study found, are those that limit their use of inquiry, then gradually stop adopting it altogether or do not use it consistently. It is also amongst these “foot-draggers” that we find the highest level of aversion to science fair, who are less involved, or who do not take part in any science fair project.

Together, these relationships suggest that teachers who utilize scientific inquiry because they feel they had the choice to do so, are those who are more likely to organize science fair projects; whereas those that have been coerced to use an inquiry-based teaching approach are also those that are more likely to appear unwilling to use it, and are also disinclined to participate in any science fair project. Therefore, this study finds that it is imperative to consider scientific inquiry and science fair as two entities linked together, in
that teachers who are not favorably disposed toward either of the two are more likely to reject both.

**Implications for Practice and Research**

The findings outlined above have clear and profound implications at a scientific level as well as for implementation of science curricula, and supporting policy making.

**Implications for Practice.** The findings of this study clearly put into context how teachers’ beliefs about science inquiry and science fair affect their adoption and implementation of these strategies as key tools to science teaching/learning. This is an important point to education policy makers in order to understand why education reforms aimed at fostering scientific inquiry, which are indispensable to developing the next cohort of scientific thinkers, have had little impact in practice. This is because most reform efforts tend to adopt a non-behavioral approach such as presenting inquiry and/or science fair projects as a specific prescription for science teachers, with no flexibility at all for teachers to exercise their abilities and discretion to shape learning. This calls for a reconsideration of future inquiry-based reform efforts to move away from merely mandated prescriptions of science curriculum to a more participative approach in which teachers play a central role, including in implementation of the science curriculum with reasonable flexibility.

This study has also shown that inquiry-based teaching requires specific skills: mastery of content knowledge (Stevens & Wenner, 1996), strong scientific competency and some inherent teaching skills (Prawat, 1992). This implies that in order to foster inquiry-based science teaching, there is a need to train teachers, especially novice teachers, in inquiry-based methods. Such training should focus on helping teachers to master their course content as well as some other content related to their domain of specialization since science fair projects typically comprise more than just one scientific domain (Abernathy & Vineyard, 2001). In
addition to training, it is imperative for experienced science teachers to mentor their new counterparts in implementing science fair projects. One practical way of accomplishing this is pairing an experienced teacher with a new teacher so they can collaborate to engage their students in science fair project development and implementation. This would reduce the planning time for teachers and allow the new teacher to gradually master the process. The mentorship program could take at least a 3-5 year period.

Furthermore, administrators who supervise teachers in science inquiry and science fair project development also need special training in inquiry and science fair so they can better support teachers in their classrooms. This is so because very often administrators do not necessarily have the science background necessary to adequately supervise science inquiry and science fair project development.

Additionally, in order to successfully foster inquiry-based learning in their classrooms, science teachers require not only help and practical support from the school, but also external mentoring to not only reduce planning time for inquiry and science fair project development and implementation, but also to help generate high level science inquiry tasks and science fair projects that foster and develop literacy skills aligned with the NGSS and NRC elements of inquiry. Schools should therefore be encouraged to develop a proper framework and allocate material resources and/or expert knowledge for such support and mentorship. This should also include providing teachers with enough time to collaborate with each other to plan and test inquiry science activities and science fair projects, as well as to engage in peer classroom observations to observe best practices. In addition, organizing science fair after high stakes exams such as the MCAS would encourage more teacher and student participation, and undoubtedly would result in higher level science fair projects, since both teachers and students would more time to complete them.

Another key finding of this study was the feeling amongst science teachers that
inquiry and science fair do not align with science curriculum. Consequently, it will be imperative to contemplate making science fair (i.e., independent research projects consistent with NRC’s five elements of inquiry) part of the MCAS requirement. The five elements of NRC inquiry in question are: Learner engages in a scientifically oriented question, learner gives priority to evidence in responding to questions, learner formulates explanations from evidence, learner connects explanation to scientific knowledge, and learner communicates and justifies explanations (NRC, 2000).

Furthermore, it is very significant to note that our education system is strongly rooted in accountability requirements and incentives. Thus, in order to foster science teachers’ adoption and implementation of inquiry and science fair as a norm in the classroom, it may be worth examining the prospect of augmenting the current science teacher evaluation system with criteria that also comprise inquiry science and science fair. The teacher evaluation system should not be based purely on one aspect of teaching, which is students’ performance on standardized test, but rather there should be a 50/50 balance between student performance results and level of inquiry implementation (Abernathy & Vineyard, 2001). This would provide an incentive for teachers to embrace inquiry; otherwise it will remain in limbo.

And finally, this study has clearly distinguished myths from the reality that surrounds teachers’ preference (or its lack thereof) for science fair projects. This information will help to promote further scientific discourse and hopefully encourage the use of science fair projects throughout the school district as a means of helping teachers to instill a deeper level of intellectual thought and critical analysis in their students. Additionally, the findings will provide a basic framework for future development of a repertoire of behavioral approaches and resources to support teachers’ shift from traditional teaching practices to 21st century teaching practices — whereby the teacher is the facilitator who models scientific inquiry skills, asks guiding questions and fosters student creativity, and where students act as
problem-solvers rather than simply fact-finders. As Vanderlinde and van Braak (2010) observed, “Building bridges between researchers and practitioners” helps create “new incentives for school improvement” (p. 312). Similarly, by building bridges between classroom instruction and the real world through inquiry, teachers can create incentives for improvement in science education.

From a personal point of view, as a science program director and administrator, this study also provides me with a basic framework for influencing positive behavior and/or behavioral change for improving science learning in my workplace. I now stand a better chance of encouraging and influencing most of the science teachers under my supervision to embrace process-based science teaching, for instance, by mentoring them to engage students in science fair projects development instead of imposing inquiry strategies as a dogma to teachers under my supervision; allowing teachers the flexibility and freedom that they deserve to take ownership of their work and design an instructional model that best fits the students they teach. In so doing, as verified by this study, teachers will begin to cultivate more positive attitudes towards inquiry, which are beneficial to their embracing it, and even encourage their colleagues and support them to practice inquiry.

**Implications for Research.** This study has contributed to enhancement of the understanding of teachers’ behaviors in the implementation of scientific inquiry, with wide-ranging implications for practice. Similarly, the study elicited numerous considerations and questions for future research.

In the first place, the findings of this study, which were predominately obtained through qualitative research methods, may require further validation with a mixed-method design, incorporating various quantitative methods in addition to the qualitative methods
used. This would help to address the subjectivity associated with qualitative research design (Creswell, 2012) that may compromise the findings herein.

Secondly, these findings should be followed up with further research to identify the best behavior change model/framework for fostering (or generally managing the implementation of) scientific inquiry and science fair in classrooms. This will support the quest of taking findings from the ‘laboratory doormat’ to the ‘doormat of classrooms,’ thereby bridging the scholar-practitioner gap that often characterizes most research endeavors (Ginsburg & Gorostiaga, 2001). This process would be guided by the following key questions: How can we apply findings from the artificial nature of a laboratory to a naturalistic situation like the classroom? How can we adapt the findings to different levels of expertise of teachers, and different levels of knowledge and competency of students? How will we accommodate the different levels of funding available, and the micro culture of each specific school? And what is the most appropriate Behavioral Change Technique (BCT) for managing scientific inquiry among science teachers?

The Word Bank’s Communication for Governance and Accountability Program (CommGAPP) identifies three main behavioral change models that could be considered for future studies. These include: Social Cognitive Theory (SCT), Theory of Planned Behavior, TPB (which constituted the theoretical framework for this study) and the Stages of Change (Trans theoretical) Model (CommGAP, 2015). Considering a similar study using SCT as the theoretical framework can bridge some of the identified gaps of TPB, such as failure to consider aspects such as self-efficacy in predicting human behavior. Additionally, the Trans theoretical Model presents six steps of behavior change for which future research could seek to establish possible application in instituting positive behavior changes for inquiry-based science practices in the classrooms based on the findings of this study.
According to Michie, Francis, Hardeman and Eccles (2008), there are about eleven determinants of behavioral change that any BCT should consider in an attempt to foster behavior change. These include: “skills, capabilities, motivations/goals, action planning, consequences, memory, emotions, social influence, role identity, environment and knowledge” (p. 668). While some of these determinants (particularly motivations, social influence, consequences and environment) are exclusively accounted for by TPB in this study; others such as skills, capabilities and memory are not considered by TPB, whereas information on the others is scanty in the lens of TPB. As such, broadening this study by considering additional theoretical frameworks would lead to more informed findings/conclusions/inferences concerning teachers’ behaviors about inquiry science and science fair, and how such behaviors can be successfully modified to encourage positive change in the science classroom.

**Study Limitations**

While this study does well in illuminating teachers’ behaviors that affect implementation of scientific inquiry, the study had several limitations.

The first set of limitations is related to the inherent limitations that attend to all qualitative studies: the futility of generalizing the findings to the population under study. This can be seen, like most qualitative studies, in the fact that this study is based on a relatively small sample (8 participants in this case), which was not randomized. A mixed method research (Hesse-Biber, 2015), combining the advantages of qualitative and quantitative research methods, would have been a possible way to partially resolve this issue; however, such a procedure goes far beyond the scope of this work.

Another limitation, with respect to methodology, is that it would have been more insightful if the interview data was cross-referenced and corroborated with actual observation
and analysis of artifacts associated with scientific inquiry and science fair projects in the classrooms of the study schools.

It is also imperative to emphasize the fact that the theoretical model used, the TPB, has been criticized by some scholars as not capable of holistically conceptualizing human behavior. As Conner (1998) notes, TPB fails to consider six main factors that play a significant role in controlling human behavior. These include a person’s belief salience, past behavior/habit, self-efficacy, moral norms, self-identity and affective beliefs. This implies that there may be other important aspects of teachers’ behavior that influence their use of inquiry-based science strategies which are not captured by this study because this study predominantly relied upon Ajzen’s (1991) TPB model in its basic form, comprising behavioral, normative and control beliefs and the resulting behavioral intentions and actual behavior and/or actual control over a given behavior.

**Conclusions and Recommendations**

**Conclusions.** Science teachers who prefer inquiry-based approaches exhibit a positive attitude towards inquiry, which is motivated by their behavioral beliefs that inquiry enhances student performance, betters the learning experience and allows students to take ownership of the learning process. This view conflicts with that of counterparts who hold a negative attitude toward inquiry, driven by their beliefs (behavioral beliefs) that inquiry does not align with the prevailing testing system, requires higher cognitive skills from students and is generally ineffectiveness. The situation is no different with the science fair. Teachers who prefer using science fair emphasize that it aligns with the current curriculum and can be combined with inquiry to deepen critical thinking among students, whereas critics see it as an ineffective approach, especially when forced down the throats of teachers.
Proponents of science inquiry are motivated by their control beliefs that inquiry aligns with their schools’ goals, which they were expected to meet. When presented as a complementary approach to other scientific processes, teachers tend to believe that science inquiry becomes a beneficial tool to science learning. However, presenting inquiry as a mandatory approach to science teaching elicits negative attitudes about inquiry amongst science teachers, thereby impeding their adoption of the strategy. Again, a similar situation is replicated with the science fair (which most teachers embrace) when presented as a complimentary approach with appropriate support from the school as well as extrinsic support, but which many teachers reject when forced upon them by school leadership.

The positive control beliefs that teachers have about their ability to teach the content needed for MCAS success using inquiry depends to a great extent on how much control (flexibility) they exercise over applying inquiry. Additionally, science teachers’ ability to implement inquiry also depends on their content knowledge, level of inborn disposition to teach, as well as support from the school. Conversely, control beliefs that impede inquiry science practice include the beliefs that there is inadequate time to implement inquiry, that inquiry is more difficult, and that teaching inquiry requires greater content knowledge. Furthermore, the existence of prescriptive requirements for teachers to embrace inquiry engenders unfavorable control beliefs about inquiry science.

When teachers are permitted a certain level of teaching flexibility in applying science inquiry and science fair, most of them implement spontaneously an inquiry-based teaching strategy and learning with their students. They also encourage and support new teachers to follow their lead. However, when inquiry is imposed upon teachers, they first start to apply it only for specific topics before beginning to lament its ineffectiveness and ultimately, discarding it entirely.
Science inquiry and science fair are closely related. Science teachers who implement inquiry with a certain level of teaching flexibility are also those who most often are actively involved in engaging their students in science fair projects, whereas teachers who do not implement inquiry, essentially because it has been imposed upon them, are those that limit their use of inquiry, then gradually abandon the practice.

**Recommendations.**

1. Scientific inquiry should be promoted as a central strategy in science teaching as a way to improve student performance in science, enhance their learning experience and assisting them to take ownership of the learning process.

2. Reform efforts devised to promote scientific inquiry in high school science classrooms should take a behavioral approach aimed at positively influencing teachers’ attitudes and subsequent embrace of inquiry as a productive approach. Never at all should such reforms seek to impose or prescribe inquiry, and/or science fair as the sole approach on all science teachers. Instead, a reasonable level of flexibility and autonomy should be afforded to science teachers to encourage them to take ownership of the teaching process with the purpose of having them develop positive attitudes for student-centered learning approaches.

3. Science fair projects that exhibit the five elements of NRC inquiry model are an important/beneficial manifestation of scientific inquiry that should be encouraged in all schools as way to promote critical thinking skills and experiential learning for students. However, as with general inquiry, teachers should be allowed discretion to choose the kinds of projects in which their students should be engaged and how they should be performed to avoid negative reactions to science fair.
4. Science curriculum should be aligned with desirable scientific approaches that promote inquiry in class as well as in development and execution of science fair projects.

5. School and district support for teachers to embrace enquiry still needs to be fostered/strengthened.

6. In an effort to further motivate participation in science fairs, teachers should consider inviting other students, parents and friends to view exhibitions and physically attend the presentations. Students in lower grades should be invited to view/judge the projects of students in higher grades, thereby exposing them to science inquiry and science fair at earlier grade. Such measures could instill confidence and encourage students’ participation, and most importantly, provide opportunities for students to experience the work of a scientist, provided that the science fair projects exhibit the elements of authentic scientific research.

7. Teacher preparation programs, as well as teacher professional development, must provide opportunity for teachers to construct their own knowledge and understanding of effective instructional practices. They must also allow teachers to develop their own theories of inquiry teaching and learning, by providing them with research field experiences. Additionally, teacher education programs and professional development must also include teaching strategies that assist teachers in not only acquiring the skills necessary for science inquiry and science fair, but also overcoming obstacles for effective inquiry science instruction.

8. Furthermore, teacher education programs and teacher professional development programs that increase self-efficacy, lower teacher/student anxiety, and increase teacher effectiveness are also essential components of furthering the goals of science education—to educate scientifically literate citizens to meet the innovative and challenging scientific needs of the 21st century. The implementation of scientific research as part of teacher
education programs – and specifically science fair projects – is, therefore, key to achieving these needs.
List of References


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National Middle School Association (NMSA). (2003). *This we believe: Successful schools for young adolescents*. Columbus, OH: Author.


National Research Council, NRC (2013). Next Generation Science Standards, NGSS.


Tarik, Tosun, (2000). The beliefs of preservice elementary teachers toward science and


Appendices

Appendix 1: Complete Description of the Proposed Data Analysis Method

Template of the individual participant’s data encoding map implementing the TPB model

(Ajzen, 2002)

Definition of the “Behavioral Level” of the TPB model (Ajzen, 2002)
Definition of the “Normative Level” of the TPB model (Ajzen, 2002)
Definition of the “Control Level” of the TPB model (Ajzen, 2002)

Definition of the “Behavioral Intention” of the TPB model (Ajzen, 2002)
Definition of the “Actual Behavioral” of the TPB model (Ajzen, 2002)
Appendix 2: Approvals

IRB approval

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NOTIFICATION OF IRB ACTION

Date: January 14, 2016

IRB #: CPS15-12-19

Principal Investigator(s): Kristal Clemons
Anne Marie De Barros Miller

Department: Doctor of Education Program
College of Professional Studies

Address: 20 Belvidere
Northeastern University

Title of Project: Investigating Teachers' Behaviors in the Implementation of Science Inquiry and Science Fair Projects in an Inner City High School

Participating Sites: Boston Public Schools approval forthcoming

DHHS Review Category: Expedited #6, #7

Informed Consents: One (1) signed consent form

Monitoring Interval: 12 months

APPROVAL EXPIRATION DATE: JANUARY 13, 2017

Investigator's Responsibilities:

1. The informed consent form bearing the IRB approval stamp must be used when recruiting participants into the study.
2. The investigator must notify IRB immediately of unexpected adverse reactions, or new information that may alter our perception of the benefit-risk ratio.
3. Study procedures and files are subject to audit any time.
4. Any modifications of the protocol or the informed consent as the study progresses must be reviewed and approved by this committee prior to being instituted.
5. Continuing Review Approval for the proposal should be requested at least one month prior to the expiration date above.
6. This approval applies to the protection of human subjects only. It does not apply to any other university approvals that may be necessary.

C. Randall Colvin, Ph.D., Chair
Northeastern University Institutional Review Board

Nan C. Regina, Director
Human Subject Research Protection

Northeastern University FWA #4630
Letter to the headmaster

Anne Marie De Barros Miller
42 BV College of Professional Studies
Northeastern University
Boston, MA 02115
North Eastern University,

Date: March 10, 2016

The Headmaster of—

Dear Sir/Madam:

RE: REQUEST FOR RECRUITMENT OF RESEARCH PARTICIPANTS

My name is Anne Marie De Barros Miller, a doctoral student from the College of Professional Studies, Northeastern University. As part of my doctoral dissertation work, I am investigating teachers’ beliefs in the implementation of science inquiry and science fair in Boston high schools. Particularly, I would like science teachers to share with me their perceptions, experiences, intentions and preferences for scientific inquiry methods in their teaching. The results of this study will go a long way not only in helping me to complete my doctoral studies, but also in the formulation of appropriate technical and policy recommendations for improving science teaching/learning in our schools.

Participants for this study must be current science teachers between 25-65 years old. They should hold a high school science teaching license, and have at least three years of experience teaching introductory high school science courses (biology, chemistry, physics, environmental science, or anatomy and physiology) in the United States.

The participants will be subjected to a 45 minutes interview to seek information. They could also be requested to share their teaching artifacts (such as lesson plans, schemes of work, class notes, class schedules and teaching resources) for analysis.

Kindly note that all information from the interview will be kept confidential, and will only be shared among members of my research team. The information will be used primarily for the research and/or any other purpose relating to the study. In the event that we include any information in the report, rest assured that identity will remain strictly concealed. Participants will reserve the right to respond only to issues which they do not mind talking about and are at will to withdraw as well as they are at will to participate.

I would appreciate if you could share this letter with your science teachers who meet the aforementioned criteria. Those willing to participate in the study are requested to contact me for further information.

Sincerely,

Anne Marie De Barros Miller
617-309-9665
debarrosa@husky.neu.edu
b) Boston Public Letter of approval

03/03/2016

Mrs. Anne Marie De Barros Miller  
Northeastern University  
20 Crest Dr  
Boston MA 02030

Dear Mrs. De Barros Miller,

I am in receipt of your research proposal entitled “Investigating Teachers’ Behaviors in the Implementation of Science Inquiry and Science Fair Projects in an Inner City High School.” Your research request has been approved with the following stipulation:

Any professional development or presentation of findings to BPS teachers or staff must first be approved by the BPS Director of K-12 Science and Technology/Engineering. To obtain approval, researcher must submit either a PD plan and/or entire presentation of findings to the BPS Director at least one month before scheduling any PD session or release of results.

Enclosed please find a copy of the Research Proposal Review Form for conducting research in the Boston Public Schools. It is your responsibility to take this form and have it signed by the Principal or Headmaster of each school (or appropriate BPS office) in which you plan to conduct research.

A copy of your executive summary (max. of 1 page) must be submitted along with the Review Form. Approval for this study is contingent upon your returning the signed consent forms to me.

If you have any questions about this matter, please feel free to contact our office at (617) 635-9450.

Sincerely,

Nicole Wagner Lam  
Executive Director  
Office of Data & Accountability  
Encl.

[Signature]

Boston Public Schools  
Tommy Chang, Superintendent

Boston School Committee  
Michael D. O’Neill, Chair

City of Boston  
Martin J. Walsh, Mayor
d. Boston Public Research Proposal Notification Form

RESEARCH PROPOSAL NOTIFICATION FORM

The research proposal described below has been:

☑ APPROVED   ☐ DISAPPROVED

Nicole Wagner Lam
Executive Director
Office of Data & Accountability

Name of Researcher: Mrs. Anne Marie De Barros Miller
Affiliation: Northeastern University
Title of Proposed Research Project: “Investigating Teachers’ Behaviors in the Implementation of Science Inquiry and Science Fair Projects in an Inner City High School”
Topic of Proposed Research Project: Inquiry Science Education
Comments: Research is approved with stipulation.
Research Proposal Review Form

03/03/2016

Dear Headmaster/Principal:

Enclosed please find an executive summary and proposal to conduct educational research in the Boston Public Schools. The proposal is being sent to you for your input. Although the Office of Data and Accountability has determined that the proposal satisfies the criteria for research outlined in the "Investigating Teachers' Behaviors in the Implementation of Science Inquiry and Science Fair Projects in an Inner City High School" research, the decision to involve your school in the study rests with you. If you need further information in regards to the research, please reach out to the Principal Researcher. Should you decide to participate in the proposed study, please return this completed form to the researcher who will forward it directly to my office.

Thank you.

Please note: Research may require a survey component; you have the discretion to opt out of the research.

Comments:

Nicole Wagner Lam, Executive Director
Office of Data & Accountability

Name of Researcher: Mrs. Anne Marie De Barros Miller
Affiliation: Northeastern University

Title of Proposed Research Project: "Investigating Teachers' Behaviors in the Implementation of Science Inquiry and Science Fair Projects in an Inner City High School"
Topic of Proposed Research Project: Inquiry Science Education

Reviewer Please check one:
☒ Proposal Supported
☐ Proposal Rejected

Reasons for rejecting proposed research:

Signature:

Please Print Your Name:

Please check one:
☒ Headmaster or Principal:
☐ Other:
☐ School:

Department:

Boston Public Schools
Tammy Chang, Superintendent

Boston School Committee
Michael D. O'Neill, Chair

City of Boston
Martin J. Walsh, Mayor
Appendix 3: Study related documents

Interview protocol

Interview Protocol

Investigating Teachers’ Beliefs in the Implementation of Science Inquiry and Science Fair in Three Boston High Schools

Target Population

This interview targets science teachers in an inner-city high school in Boston. Science teachers are targeted so as to explore their beliefs in the implementation of science inquiry and science fair in their schools. This is because teachers are the principal curriculum implementers in the school. Understanding their beliefs in science inquiry implementation is fundamental to conceptualizing the state of science teaching and learning in the school, and recommending appropriate measures for improvement. This interview targets three facets of human behavioral influences namely, behavioral beliefs, normative beliefs and control beliefs in the context of the Theory of Planned Behavior.
BEFORE THE INTERVIEW

<table>
<thead>
<tr>
<th>Introduction Checklist</th>
<th>I am extremely grateful to you for sparing your precious time to meet me today. My name is Anne Marie De Barros, from the College of Professional Studies, Northeastern University, Boston MA. As part of my graduate research work, I am investigating teachers’ practices in the implementation of science inquiry and science fair in Boston’s inner-city high schools. Particularly, I would like for you, as a science teacher, to share with me your perceptions, experiences, intentions and preferences for scientific inquiry in your teaching. The results of this study will go a long not only in helping me complete my doctoral studies, but also in the formulation of appropriate technical and policy recommendation for improving science teaching and learning in our schools. The interview is scheduled to take a period of one hour. During the interview session, I will be taking brief notes in order to capture key points of your comments. However, I recognize the fact that I may not be in a position to write down everything you say on my notes during the interview. As a result, I would like to request that I tape the entire interview session to allow me to capture and analyze the full details of your points. In that case, I would appreciate if you can speak clearly to enable me to record your comments. Please note that all your responses in this interview will be kept confidential and will only be shared among members of our research team. The information will be used primarily for the research and/or any other purpose relating to our study. In the event that we include any information from this interview, in our report, rest assured that your identity would remain strictly concealed. You are free to respond only to issues you do not mind talking about. In addition, while your contribution to this study will be highly appreciated, you reserve the right to withdraw your participation in this interview at any given time. May I know if you have any questions or comments about my explanation? To this extent, if you are willing to take part in the interview, kindly sing this form.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Checklist</td>
<td></td>
</tr>
<tr>
<td>✓ Appreciation</td>
<td></td>
</tr>
<tr>
<td>✓ Self-introduction</td>
<td></td>
</tr>
<tr>
<td>✓ Purpose of study</td>
<td></td>
</tr>
<tr>
<td>✓ Time frame</td>
<td></td>
</tr>
<tr>
<td>✓ Mode of interview</td>
<td></td>
</tr>
<tr>
<td>✓ Confidentiality</td>
<td></td>
</tr>
<tr>
<td>✓ Questions/clarifications</td>
<td></td>
</tr>
<tr>
<td>✓ Statement of consent</td>
<td></td>
</tr>
</tbody>
</table>

Interviewee  Witness  Date
<table>
<thead>
<tr>
<th>Prompts</th>
<th>Interview Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Name</td>
<td>1. Could you please tell me about your background and teaching experience?</td>
</tr>
<tr>
<td>✓ Current position</td>
<td></td>
</tr>
<tr>
<td>✓ Teaching experience</td>
<td></td>
</tr>
<tr>
<td>✓ Number of schools taught</td>
<td></td>
</tr>
<tr>
<td>✓ Personal positionality</td>
<td>2. Professional education literature, standards and bodies such as the National Research Council advocate for inquiry as a central strategy in science instruction. Please share with me your personal beliefs and experience about inquiry and its effectiveness in science teaching and learning.</td>
</tr>
<tr>
<td>✓ Personal beliefs/opinions</td>
<td></td>
</tr>
<tr>
<td>✓ School’s support for inquiry</td>
<td>3. Please comment on the position of your school concerning science inquiry and how this influences your teaching approaches.</td>
</tr>
<tr>
<td>✓ Any extrinsic motivating factors</td>
<td></td>
</tr>
<tr>
<td>✓ Participation</td>
<td>4. Please comment on your position concerning science fair projects and the extent of your school’s support for science fair projects and participation in science fair competitions.</td>
</tr>
<tr>
<td>✓ No Participation</td>
<td></td>
</tr>
<tr>
<td>✓ Frequency of participation</td>
<td></td>
</tr>
<tr>
<td>✓ Reason for participation</td>
<td></td>
</tr>
<tr>
<td>✓ Attitude about science fair projects and science fair competitions</td>
<td></td>
</tr>
<tr>
<td>✓ School support for science fair</td>
<td></td>
</tr>
<tr>
<td>✓ Teacher-centered</td>
<td>5. With respect to science teaching and learning approaches (inquiry-based and otherwise), how would you describe the most perfect science teaching and learning approach for you and why?</td>
</tr>
<tr>
<td>✓ Student centered/inquiry-based</td>
<td></td>
</tr>
<tr>
<td>✓ Combination</td>
<td></td>
</tr>
<tr>
<td>✓ Attitude – direction</td>
<td>6. From your observation, interaction, and work with other science teachers, what would you say is their attitude concerning science inquiry and science fair projects?</td>
</tr>
<tr>
<td>✓ Attitude - intensity</td>
<td></td>
</tr>
<tr>
<td>✓ Forced to implement inquiry</td>
<td>7. What role do state-mandated tests, curriculum and accountability requirements play in influencing your teaching practice with respect to science inquiry and science fair projects?</td>
</tr>
<tr>
<td>✓ Denied time for inquiry</td>
<td></td>
</tr>
<tr>
<td>✓ Teaching to the test</td>
<td></td>
</tr>
</tbody>
</table>
## AFTER THE INTERVIEW

<table>
<thead>
<tr>
<th>Closing Remarks</th>
<th>Before we come to a close, is there anything you would like to add?</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Request for Any Additional Comments</td>
<td>Your responses will indeed play a crucial role in our study about science inquiry. I am going to analyse the information I have received from you and other respondents. I will then write a report of the findings of the study and submit it for examination by my university. The report will also be forwarded to other relevant education stakeholders. If you are interested in receiving a copy, I would not mind sending it to you.</td>
</tr>
<tr>
<td>✓ Way Forward/Next Steps</td>
<td>Just in case I need any further clarifications of your responses, may I contact you? Here is my contact information. May I have your contact information as well?</td>
</tr>
<tr>
<td>✓ Appreciation</td>
<td>Thank you very much for your time.</td>
</tr>
</tbody>
</table>
Appendix D

Consent Form

Northeastern University, College of Professional Studies

Name of Investigator(s): Dr. Kristal Clemens (Principal Investigator)
Anne Marie De Barros Miller (Student Researcher)

Title of Project: Investigating Teachers’ Beliefs in the Implementation of Science Inquiry and Science Fair Projects in an Inner City High School

Request to Participate in Research

We would like to invite you to take part in a research project. The purpose of this research is to explore teachers’ attitudes and opinions regarding the teaching of inquiry science and to affect productive change.

You must be at least 18 years old to be in this research project.

The study will take place at [insert location] and will take about [insert time]. If you decide to take part in this study, we will ask you to participate in one interview (conducted by Anne Marie De Barros Miller) about your opinion of inquiry science teaching.

There are no foreseeable risks or discomforts to you for taking part in this study.

There are no direct benefits to you for participating in the study. However, your answers may help us to learn more about inquiry science teaching.

Your part in this study will be handled in a confidential manner. Only the researchers will know that you participated in this study. Any reports or publications based on this research will use only group data and will not identify you or any individual as being of this project.

The decision to participate in this research project is up to you. You do not have to participate and you can refuse to answer any question. Even if you begin the study, you may withdraw at any time.

If you have any questions about this study, please feel free to call, Anne Marie De Barros Miller (Tel: 617-373-4588), email: Debarros.self@husky.neu.edu; the person mainly responsible for this research. You can also contact Kristal Clemens (Northeastern University, Boston MA, Email: klclemens@neu.edu), the Principal Investigator.

If you have any questions about your rights in this research, you may contact Nan C. Regina, Director: Human Subject Research Protection, 460 Renaissance Park, Northeastern University, Boston, MA 02115, Tel: 617-373-4588. Email: ncregina@neu.edu. You may call anonymously if you wish.

You may keep this form for yourself.

Thank you.

Anne Marie De Barros Miller
Agreement of confidentiality for transcription

CLIENT NON-DISCLOSURE AGREEMENT

This CLIENT NON-DISCLOSURE AGREEMENT, effective as of the date last set forth below (this “Agreement”), between the undersigned actual or potential client ("Client") and Rev.com, Inc. ("Rev.com") is made to confirm the understanding and agreement of the parties hereto with respect to certain proprietary information being provided to Rev.com for the purpose of performing translation, transcription, video captions and other document related services (the "Rev.com Services"). In consideration for the mutual agreements contained herein and the other provisions of this Agreement, the parties hereto agree as follows:

1. Scope of Confidential Information

1.1. "Confidential Information" means, subject to the exceptions set forth in Section 1.2 hereof, any documents or other text supplied by Client to Rev.com for the purpose of performing the Rev.com Services.

1.2. Confidential Information does not include information that: (i) was available to Rev.com prior to disclosure of such information by Client and free of any confidentiality obligation in favor of Client known to Rev.com at the time of disclosure; (ii) is made available to Rev.com from a third party not known by Rev.com at the time of such availability to be subject to a confidentiality obligation in favor of Client; (iii) is made available to third parties by Client without restriction on the disclosure of such information; (iv) is or becomes available to the public other than as a result of disclosure by Rev.com prohibited by this Agreement; or (v) is developed independently by Rev.com or Rev.com’s directors, officers, members, partners, employees, consultants, contractors, agents, representatives or affiliated entities (collectively, "Associated Persons").

2. Use and Disclosure of Confidential Information

2.1. Rev.com will keep secret and will not disclose to anyone any of the Confidential Information, other than furnishing the Confidential Information to Associated Persons; provided that such Associated Persons are bound by agreements respecting confidential information. Rev.com will not use any of the Confidential Information for any purpose other than performing the Rev.com Services on Client's behalf. Rev.com will use reasonable care and adequate measures to protect the security of the Confidential Information and to attempt to prevent any Confidential Information from being disclosed or otherwise made available to unauthorized persons or used in violation of the foregoing.

2.2. Notwithstanding anything to the contrary herein, Rev.com is free to make, and this Agreement does not restrict, disclosure of any Confidential Information in a judicial, legislative or administrative investigation or proceeding or to a government or other regulatory agency; provided that, if permitted by law, Rev.com provides to Client prior notice of the intended disclosure and permits Client to intervene therein to protect its interests in the Confidential Information, and cooperate and assist Client in seeking to obtain such protection.

3. Certain Rights and Limitations

3.1. All Confidential Information will remain the property of Client.

3.2. This Agreement imposes no obligations on either party to purchase, sell, license, transfer or otherwise transact in any products, services or technology.

4. Termination

4.1. Upon Client’s written request, Rev.com agrees to use good faith efforts to return promptly to Client any Confidential Information that is in written and in the possession of Rev.com and to certify the return or destruction of all Confidential Information, provided that Rev.com may retain a summary description of Confidential Information for archival purposes.

4.2. The rights and obligations of the parties hereto contained in Sections 2 (Use and Disclosure of Confidential Information) (subject to Section 2.1), 3 (Certain Rights and Limitations), 4 (Termination), and 5 (Miscellaneous) will survive the return of any tangible embodiments of Confidential Information and any termination of this Agreement.

5. Miscellaneous

5.1. Client and Rev.com are independent contractors and will so represent themselves in all regards. Nothing in this Agreement will be construed to make either party the agent or legal representative of the other or to make the parties partners or joint venturers, and neither party may bind the other in any way. This Agreement will be governed by and construed in accordance with the laws of the State of California governing such agreements, without regard to conflicts-of-law principles. The sole and exclusive jurisdiction and venue for any litigation arising out of this Agreement shall be an appropriate federal or state court located in the State of California, and the parties agree not to raise, and waive, any objections or defenses based upon venue or forum non conveniens. This Agreement (together with any
agreement for the Rev.com Services) contains the complete and exclusive agreement of the parties with respect to the subject matter hereof and supersedes all prior agreements and understandings with respect thereto, whether written or oral, express or implied. If any provision of this Agreement is held invalid, illegal or unenforceable by a court of competent jurisdiction, such will not affect any other provision of this Agreement, which will remain in full force and effect. No amendment or alteration of the terms of this Agreement will be effective unless made in writing and executed by both parties hereto. A failure or delay in exercising any right in respect to this Agreement will not be presumed to operate as a waiver, and a single or partial exercise of any right will not be presumed to preclude any subsequent or further exercise of that right or the exercise of any other right. Any modification or waiver of any provision of this Agreement will not be effective unless made in writing. Any such waiver will be effective only in the specific instance and for the purpose given.

IN WITNESS WHEREOF, the parties have caused this Agreement to be executed below by their duly authorized signatories.

CLIENT

Print Name: __________________________

By: ________________________________

Name: ______________________________

Title: ______________________________

Date: ______________________________

Address for notices to Client:

______________________________

______________________________

______________________________

REV.COM, INC.

By: ________________________________

Name: Cheryl Brown

Title: Account Manager

Date: February 1, 2016

Address for notices to Rev.com, Inc.:

251 Kearny St, Suite 800
San Francisco, CA 94108
Determine Not direct measure
of subjective norm

Determine Not direct measure
of perceived behavioral control

TPSI - 4.0.

Results — Participant n — Name — v2.0.0

1. Behavioral level

1.1. Behavioral beliefs

Definition = beliefs of possible outcomes of own behavior

Scientific inquiry Favorable Unfavorable
Science fair Favorable Unfavorable

1.2. Attitude towards beliefs

Definition = Positive / negative evaluation about performing particular behavior

Scientific inquiry Favorable Unfavorable
Science fair Favorable Unfavorable

2. Normative level

2.1. Normative beliefs

Definition = belief of others' expectations

Scientific inquiry Favorable Unfavorable
Science fair Favorable Unfavorable

2.2. Subjective norm

Definition = Perceived social pressure to engage/not in behavior

Teachers

Scientific inquiry Favorable Unfavorable
Science fair Favorable Unfavorable

School

Scientific inquiry Favorable Unfavorable
Science fair Favorable Unfavorable

Mandated test

Scientific inquiry Favorable Unfavorable
Science fair Favorable Unfavorable

3. Control level

3.1. Control beliefs

Definition = beliefs about factors impacting performance behavior

Scientific inquiry Favorable Unfavorable
Science fair Favorable Unfavorable

3.2. Perceived behavioral control

Definition = perceived capacity for performing behavior

Scientific inquiry Favorable Unfavorable
Science fair Favorable Unfavorable
INVESTIGATING TEACHERS’ BELIEFS IN THE IMPLEMENTATION OF SCIENCE INQUIRY AND SCIENCE FAIR IN THREE BOSTON HIGH SCHOOLS

Doctoral Dissertation
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Northeastern University, Boston

August 2, 2016

Merged findings from all participants

Committee Members:
Dr. Kristal Clemons
Dr. Lynda Beltz
Dr. Donald A. DeRosa
1 Behavioral level

1.1 Behavioral beliefs

1.1.1 Scientific inquiry

1.1.1.1 Favorable

= Broad impact on student learning
Benefits for students
Can be very effective
Can be engaging
+ Improve student performance & learning experience
  = Assessing student's background knowledge
    Assess Students' prior knowledge
    Way of scaffolding content for students
    Using inquiry to connect learning to real life experiences

+ Enhancing student's cognitive functioning
  Increase retention of concepts
  Helping with content retention & expansion
  Better understanding by students
  Allowing to enhance students' ideas
  Significant improvement in students
  Best way to get higher level of understanding
  Advantageous for special education students

+ Generating positive emotional experience
  Good for generating curiosity in students
  Effective in engaging students
  Wonderful experience for students

=> Translating to students' academic success
  Helping student pass mandated test
  Performing better in standardised test in principle

& Preparing for scientific literacy
  Support scientific thinking in students
  Convincing students of scientific principles

-> Leading to student ownership of learning
  Student designing own procedure
  Total learning control by student
  Student owing up educational process

& Helping designing science fair project

=> Optimal teaching approach
Enhance teaching process
  Using inquiry to gauge student's mind
  Differential learning approach for student
  Using claim evidence & reasoning for learning
Favorable teaching method

Student centre inquiry-based learning as best teaching method
Best teaching learning method
Introducing inquiry at elementary level

1.1.1.2 Unfavorable
= Having core weaknesses
  Difficult to establish required foundations
  Requiring scaffolding
  Not always effective
  Very difficult to implement in biology
+ Not align with current test-based education
  Not always beneficial for test success
  Not preparing student for college
& Requiring high cognitive skills from students
  Requiring capacity of reading direction from students
  Requiring high level thinking from students
  Hard if student not able to answer open ended directed task
Students fear taking academic risks

1.1.2 Science fair

1.1.2.1 Favorable
= Align with teaching curriculum
  Relevant in term of curriculum
  Intrinsic value of science fair
+ Improve student performance & learning experience
  = Enhancing student's project skills
    = Teaching project management to students
    + Presentation of project outcomes
    + Teaching stress management
    => Learning transferable investigation skill
+ Generating positive emotional experience
  = Positive experience for students
  + Boost students' confidence
  + Leading to sense of pride in students
  => Drives student to doing better
=> Helping in being successful at MCAS
& Preparing for scientific literacy
  = Manipulation of sophisticated equipment
  + Opportunity for students to work with real scientists
  & Understand actual scientific process
-> Leading to student ownership of learning
  = Allowing students to explore topic of interest
+ Personalised exploration based student's interest
& Not necessarily detrimental to SPED students
& Possibility to combine with science Inquiry

1.1.2.2 Unfavorable
= Not implemented by some teachers & schools
Not many schools doing science fair
Not taking part because time commitment
Hated by other teachers since representing extra work
since overall inefficacy to improve learning
Small impact on content learnt
Outdated method of presentation of project outcomes
Not helping student to become researcher
Ineffectiveness of science fair
Student Pigeonholed into learning
& challenging for some students
Challenging for ELL students
Challenging for shy students
Mixed outcome depending on student

1.2 Attitude toward behavior
1.2.1 Scientific inquiry
1.2.1.1 Favorable
= Positive attitude toward inquiry
Like Inquiry
Enjoy doing science inquiry
Strong belief in scientific Inquiry
since versatile teaching approach
Scientific Inquiry instrumental to students' understanding
Great if differentiated for student needs
Useful prior to Evidence-Based Argumentation (EBA)
=> Teaching method of choice
Preferred teaching method
Support inquiry-based teaching
Prerequisite for living science
Not exclusive teaching method

Dependent on students' needs and experience
Dependent on student population and experience
Combination of Inquiry-based direct teaching as best teaching approach

1.2.1.2 Unfavorable
= More time required
For students to learn
For teachers to manage
+ Specially not adapted to special education students
& Inquiry just another education fashion
=> Should not be only methodology
1.2.2 Science fair
1.2.2.1 Favorable
= Positive attitude toward science fair
+ Love of science fair
+ Strong support for science fair
= Good thing to do
+ Worth it
=> Appreciated by all teachers
+ Seen as beneficial to students
= Adapted for students with natural curiosity
+ Way to foster student' inquiry skills
& Good way to encourage students
=> Could be good experience for some students
& Preparing for scientific career
= For teaching application of scientific method
& Teaching to be a scientist
But should not be mandatory
1.2.2.2 Unfavorable
= Inefficient usage of time
= Requiring to be done in class
+ Less time to cover actual content
=> Not teaching important concepts due to time used for science fair
+ Not relevant to preparing to become scientist
+ Not realistic compared to actual research activity
= Defence-type of presentation more suitable
+ Not best way to learn science
& Seems to be superficial
=> Questioning validity/purpose of science fair
=> Strong negative feelings against
Not worth the investment
Dislike of science fair day

2 Normative level
2.1 Normative beliefs
2.1.1 Scientific inquiry
2.1.1.1 Favorable
= Understood as fully open Inquiry by some people
+ Usually aligned to school's goals
+ Beneficial if presented as complementary approach
+ Requiring Claim Evidence Reasoning (CER) approach to structured inquiry teaching
  => Necessity skilful implementation of Inquiry

2.1.1.2 Unfavorable
  = Not practical when presented as mandatory approach
  & If starting directly with Inquiry approach

2.1.2 Science fair
  2.1.2.1 Favorable
  = If not presented as mandatory
  2.1.2.2 Unfavorable

2.2 Subjective norm
  2.2.1 Teachers
    2.2.1.1 Scientific inquiry
      Favorable
      = Beneficial to students
        = Intrinsic value of inquiry-based teaching
        Since instrumental to students’ understanding
        but no dogmatism
        = Some teachers using only Inquiry approach
        but should not be exclusive teaching method
        & Encourage flexible implementation of inquiry-based teaching
        => Improve teaching practice
        = Team work in constructing own inquiry approach
        => Implementing best practices
      Unfavorable
      = Use depending on type of student
      & Requiring enough content knowledge from teachers
      + Some teachers like concepts but not practically applicable
      + Often misconception from teacher against inquiry

2.2.1.2 Science fair
  Favorable
  = Support science fair participation
  & Supporting running of science fair
  Unfavorable

2.2.2 School
  2.2.2.1 Scientific inquiry
  Favorable
  = Strong incitement for implementation
  = Very supportive to inquiry-based teaching
  => Pushing for evidence-based argumentation from some schools
Strong encouragement of scientific inquiry model
But school opened to other approach
  = Align with inquiry
  but lot of freedom from school
  & Not mandating a particular approach
Unfavorable
  = Not supported anymore by school

2.2.2 Science fair
Favorable
  = Strong incitement for implementation
    = Strongly supported by school administration
    & Encouraging science fair participation
    & Providing materialistic support
      Supporting logistically science fair
      Supporting running of science fair
Unfavorable
  = Mandated by school manager

2.2.3 Mandated test
2.2.3.1 Scientific inquiry
Favorable
  = Standardised test supported by inquiry
    since MCAS perfectly aligned with inquiry-based approach
    => Not influencing teaching method
Unfavorable
  = Important negative impacts on teaching
    = Risk getting stuck going through content for teachers
    + Making Inquiry-based teaching more difficult
    => Source of pressure
    + Making teaching harder
    & Feeling of responsibility for teachers
    => Influencing a lot teaching practice
    & Eliciting strong negative feelings
      = Risk impacting love of learning in students
      => Deterring reason to make students to love science
      & Deterring reason of love of science for teachers
2.2.3.2 Science fair
Favorable
  = MCAS perfectly aligned with science fair
Unfavorable
  = Standardised test playing role in not doing science fair
3 Control level

3.1 Control beliefs

3.1.1 Scientific inquiry

3.1.1.1 Favorable

= Effective teaching method
  Useable for doing science fair project
  Situation of non concrete learning objective
  Good teaching method
Requiring good teaching skills
  = Facilitated by teaching experience
  + Good control of content knowledge
  + knowledge of teaching pedagogy & students’ needs
  But not requiring expertise as a scientist to do Inquiry
to fully benefit students
  = Requiring rote knowledge first
  + Could be used to deepen initial understanding
  + Complementing direct teaching with inquiry to resolve misconceptions
 & Can be complemented with evidence based argumentation
especially if used flexibly
  = Freedom to structure teaching approach
  + To be adapted to teaching situation
  + Choice to apply/not scientific Inquiry
 => Possibility of mixed approach to teaching
 Even if for some teachers direct and Inquiry required for any teaching

3.1.1.2 Unfavorable

= Time required to implement Inquiry approach
 & Inquiry-based teaching harder

3.1.2 Science fair

3.1.2.1 Favorable

= Possibility of external student mentoring support

3.1.2.2 Unfavorable

= Time commitment real issue
  = Can be very time consuming
  + Limiting time available for science fair activity
 & Not compatible with time required to meet MCAS objectives
 => Time as biggest obstacle to science fair
 => Interference with other teaching commitments
  = Competing with extra support to students
 & Date not suitable with other teaching commitment

3.2 Perceived behavioral control

3.2.1 Perceived capacity
3.2.1.1 Scientific inquiry

Favorable
- Still be able to teach content needed for MCAS
- But necessity mastery of content knowledge
- + Certain level of inborn disposition to teaching
- & Support from school

Unfavorable
- = If limited teacher content knowledge
- + Inefficiency of prescription-based teaching
- & MCAS handcuff not allowing full usage of Inquiry-based teaching

3.2.1.2 Science fair

Favorable
- = If controlling project focus

Unfavorable
- = Difficult to implement due to lack of knowledge for other science discipline
- + Highly demanding
  - = High resource required
  - & Timing inadequate in comparison to content covered
- & Important stress factor
  - = Challenging for teacher & students
  - + Stressful experience for teacher & students
  - => Impossible to do for whole class / school
  - => Mixed feelings in general about science fair

3.2.2 Perceived factors

3.2.2.1 Scientific inquiry

Favorable
- + Current standard not stopping inquiry in certain topics
  but more likely applied with new standard

Unfavorable
- = MCAS impeding use of inquiry
  - = Focusing on knowledge about facts
  - & Not capturing scientific skills
- + Threat to inquiry-based learning
  - = Source of pressure for applying inquiry
    because limiting time available for inquiry-based activity
  - => Killing a lot of inquiry
  - => Pushing to abandon inquiry teaching
- + Conflicting with preparing students to MCAS
  - = Not suitable to prepare for MCAS
  since pressure on students to prepare for tests
  - => MCAS as handcuff not allowing science fair participation
& Competing with more important matters
  = Teachers' evaluation based on MCAS success rate
  + MCAS = Determining future for schools, teachers, students
  => inquiry = Less important than achieving tests

3.2.2.2 Science fair
  Favorable
  = External support
  = Receiving technical support from partners
  & Importance of mentoring for student provided by a company
  = More likely to participate with new standard
  Unfavorable
  = Although required to participate to science fair for some
  since science fair not required to pass MCAS
  other not participating in science in order to cover MCAS content

4 Intention
4.1 Scientific inquiry
  4.1.1 Favorable
  4.1.1.1 = Desire helping student to reflect
  4.1.1.2 + Wanting to expose students to Inquiry activities
  4.1.1.3 -> Advocating of science inquiry process
  4.1.1.4 => Inquiry = Goal for science team
  4.1.2 Unfavorable

4.2 Science fair
  4.2.1 Favorable
  4.2.1.1 = Potentially awesome activity to do
  4.2.1.2 + Trying implementation despite school requirement
  4.2.1.3 by preparing it throughout the year
  4.2.1.4 -> Advocating doing science fair
  4.2.1.5 => Everybody would loved doing science fair
  4.2.2 Unfavorable
  4.2.2.1 = Necessity balance between inquiry-based other learning styles

5 Behavior
5.1 Scientific inquiry
  5.1.1 Favorable
  5.1.1.1 = Implementation of inquiry-based teaching and learning
  5.1.1.2 but keeping certain level of teaching flexibility
  = Implementing "student's own procedure" approach
  & Direct teaching/lecture followed by inquiry
  => Sliding scale approach to inquiry
Scaffolded inquiry
Completely open inquiry

5.1.1.3 & Encouraging new teachers to implement Inquiry approach

5.1.2 Unfavorable
5.1.2.1 = Implemented based on topic

5.2 Science fair

5.2.1 Favorable
5.2.1.1 = Very popular amongst teachers
= If one teacher 1st organising science fair
most teacher organised several science fair projects
& some involved in science fair for most career
5.2.1.2 adopting a student-centre approach to science fair
= Encouraging students to participate in science fair
+ Selecting suitable students for science fair
+ Offering them template examples
+ Sending them to external inquiry labs
+ Adapting curriculum to suit science fair
& Supporting newcomers students with science fair
5.2.1.3 & Supporting other teachers
= Encouraging other teachers to implement science fair
+ Helping them organise science fair

5.2.2 Unfavorable
5.2.2.1 = Some not actively participating any more
5.2.2.2 & other not taking at all part in science fair