AN ANALYSIS OF SCIENCE INSTRUCTIONAL BELIEFS AND ACT SCIENCE ACHIEVEMENT

by

Jeff Porter

A Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree of
Doctorate in Education

Middle Tennessee State University
December 2016

I dedicate this dissertation work to my son, Samuel.

ACKNOWLEDGEMENTS

This process would have never been possible without my loving, caring wife. Her support and endurance throughout this degree program has not gone unnoticed and will be forever appreciated. I would also like to thank my grandfather. Without him, this degree would have never been possible. I would also like to thank my son. He has shared his first seven months of life with a dissertation. Now he has my full attention.

ABSTRACT

Preparing secondary students for the ACT Science assessment requires giving them a skill set of reasoning that can be developed over the course of several school years. Much of this development depends on the science instruction that takes place in classrooms. Because the ACT Science assessment is not based on any single discipline or course, it is up to school science teachers collectively to prepare students with the necessary skill sets. This study used the Teacher Beliefs about Effective Science Teaching (TBEST) questionnaire as a measurement of instruction taking place in science classrooms. The questionnaire served two purposes: to measure teacher beliefs in relation to science instructional Learning Theory and to measure alignment of beliefs among science teachers. The factors of beliefs corresponding to science instruction Learning Theory and the alignment of beliefs between science teachers were statistically compared to ACT Science achievement. Teachers from four schools in a southeastern United States school district participated in the study. Results of the study showed similar beliefs about science instruction among teachers in each school's science department and between schools in the school district. The results also indicated that the school district experienced growth in ACT Science achievement over the course of three years. The sample size of the study, however, hindered identification of a correlation between teacher beliefs about science instruction and ACT Science achievement.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Introduction

The ACT test is a time-tested measure of college and career readiness, widely used as a college admission test across the United States (ACT, Inc., 2016a). This study focused on a U.S. school district in which the ACT was used not only as a college admission tool, but also as an accountability factor for secondary schools. The school district also used ACT data to inform instructional practices and policy. In this study, the researcher examined a school district whose leaders desired to improve students' ACT scores. The study specifically showed the contribution of science departments toward ACT achievement.

The ACT comprises four parts: English, math, reading, and science (ACT, Inc., 2016a). This study focused only on the ACT Science test, which allowed the researcher to investigate more effectively the contribution of a smaller group of teachers working within a single discipline. Specifically, the researcher examined the instructional beliefs of teachers in one school district as evidence toward their instructional practice in science classrooms.

Science instruction should be informed by aspects of pedagogy specific to the science discipline (Weiss, Pasley, Smith, Banilower, & Heck, 2003). Banilower, Cohen, Pasley, and Weiss (2010) claimed these pedagogical aspects should include motivating students, surfacing students' prior knowledge, engaging students with phenomena, having students use evidence to create and criticize claims, and providing opportunities for students to make sense of what they encounter in lessons. The aspects of motivation, surfacing prior knowledge, engagement with phenomena, using evidence, and sense-making within science are complemented by the *nature of science* (NOS) concept. Nature of science refers to the epistemology behind forming a deeper understanding of a concept of science (Lederman, 2006).

Banilower et al.'s (2010) concepts of pedagogy and the nature of science can be utilized in parallel with the specific content of science courses. The ability to tailor this pedagogy to support specific content within science can be described by the term *pedagogical content knowledge* (PCK). Pedagogical content knowledge involves unique classroom instruction properties based on the content being taught (Shulman, 2015).

Beyond students preparing on their own to take the ACT assessment, in this study, the researcher sought to confirm classroom instruction as a probable source for improving ACT achievement. At the time of this study, the school district had a proven history of low scores on both ACT Reading and ACT Science tests. New initiatives in the school district had started to address ACT Reading test achievement. Addressing ACT Science achievement, however, was excluded from discussions. Student improvement on ACT Science scores can help increase overall ACT scores because each subtest on the ACT is weighted equally and averaged into the ACT composite score.

Governing state departments dictate science standards for school districts. These standards reflect the content students need to learn. ACT Science standards, however, emphasize the skill sets of reasoning and data analysis in the context of science content

(ACT, Inc., 2014). Realigning instruction to address the ACT standards can help improve achievement on the ACT Science assessment of (Dufour, Dufour, & Eaker, 2008; Popham, 2011; Wormeli, 2006).

Improving ACT Science achievement can start with the instruction taking place in science classrooms. ACT Science standards and the content standards of a science course can be synthesized into instruction. As a result, preparing students for ACT Science can be viewed as a collective effort between members of a science department. Students are prepared for ACT Science within courses over several school years. This differs from a content-based assessment in which the preparation of students is the responsibility of individual teachers during a single school year.

This study was intended to begin the discussion on steps to improve scores on the ACT Science test by exploring science instruction throughout a school district. The researcher gathered data on science teacher beliefs on science instruction and compared them with student achievement on the ACT Science test. These data were used for the following analysis:

1. The alignment of teachers' instructional beliefs with the aspects of science pedagogy proposed by Banilower et al. (2010);
2. The alignment of teachers' instructional beliefs among teachers in science departments;
3. The alignment of teachers' instructional beliefs between the schools in the school district; and

4. A comparison of schools with higher and lower ACT Science achievement scores with teacher instructional belief scores.

The exploration was accomplished by gathering data on teacher beliefs about science instruction. Teacher beliefs about science instruction can be a strong indicator of the instruction taking place in classrooms (Brickhouse, 1990; Cronin-Jones, 1991; Lederman et al., 2002; Luft & Roehrig, 2007; Lumpe, Haney, & Czerniak, 2000; Magnusson, Krajcik, & Borko, 1999; Sampson, Enderle, & Grooms, 2013; Smith, Smith, & Banilower, 2014; Wong & Luft, 2015; Yerrick, Parke, & Nugent, 1997). Understanding the current status of science instruction beliefs within a school district can inform decisions about improving science instruction. This foundation is necessary before designing specific professional development that targets ACT Science achievement.

Setting

At the time of this study, the southeastern U.S. school district of focus emphasized the ACT as both a college readiness exam for students and an accountability factor for schools. The science portion of the ACT test specifically served as part of the context of the study. Participants were drawn from the science departments of various schools within the focus school district. Each participant in the study responded to items presented on an online survey.

The beliefs about instructional practices of science teachers were investigated using the Teacher Beliefs about Effective Science Teaching (TBEST) questionnaire (Smith et al., 2014). The questionnaire was designed as a quantitative data collection and analysis tool. In this study, the modes of analysis varied based on the research question being addressed. Analyses techniques included descriptive statistics and an analysis of variances aimed at addressing (a) the responses to the TBEST questionnaire, (b) alignment of beliefs to certain aspects of pedagogy, and (c) alignment of beliefs within schools and between schools in the school district. ACT Science achievement was addressed by analyzing the variances between different cohorts as well as by comparing achievement with the mean responses and alignment of beliefs data gathered from the TBEST questionnaire.

Theoretical Framework

Effective science instruction should align with the goal of promoting conceptual change among students (Banilower et al., 2010). Lederman (2006) described this conceptual change as the processes and thinking necessary to bring about scientific knowledge. Banilower et al. (2010) argued the pedagogy that promotes the thinking necessary to build scientific knowledge most effectively includes motivating students, surfacing prior knowledge, presenting phenomena, using evidence, and encouraging sense-making.

Building science knowledge goes beyond memorizing concrete concepts. Students must embrace the exploration factors and understand how theory contributes to building scientific knowledge (Lederman, 2006). Nature of science (NOS) has roots in the epistemology underlying formulating scientific knowledge (Lederman, 2006). However, Lederman noted NOS is not a central focus in primary, middle, and secondary classrooms, limiting the depth to which students understand science as a discipline.

Science instruction, therefore, needs to incorporate the pedagogical factors of motivating, surfacing prior knowledge, engaging with phenomena, using evidence, and sense-making, along with NOS and the specific content of a science course. Brickhouse (1990) described the understanding of both specific science content and the NOS behind that content as *content knowledge*. Teachers need to be able to tailor instruction to the specific content knowledge being addressed. The ability to align content knowledge with the specific pedagogy that best promotes learning is termed *pedagogical content knowledge* (PCK; Shulman, 2015).

Shulman (2015) argued that PCK is a defining aspect of science instruction. The components of PCK presented in literature have focused on pedagogy and specifically promoted the content of an individual discipline (Bransford, Brown, & Cocking, 1999; Gess-Newman, 1999; Lee & Luft, 2008; Magnusson et al., 1999). However, Van Driel and Berry (2010) argued that PCK is an elusive concept that is difficult to define and measure. Even without a single definition or collective agreement on the concrete components that comprise PCK, researchers have still recommended that educators develop PCK (e.g., Daehler, Heller, & Wong, 2015). Daehler et al. (2015) specifically identified a strong sense of content knowledge and collaboration as factors that promote the development of PCK.

The process of measuring and monitoring the development of PCK is largely absent from literature (Van Driel & Berry, 2010). However, classroom instruction is a mode of measuring PCK that has been linked to measuring teacher beliefs. Previous researcher have tied teacher beliefs to the instruction taking place within classrooms (e.g., Brickhouse, 1990; Cronin-Jones, 1991; Lederman et al., 2002; Luft & Roehrig, 2007; Lumpe et al., 2000; Magnusson et al., 1999; Sampson et al., 2013; Smith et al., 2014; Wong & Luft, 2015; Yerrick et al., 1997). However, certain variables related to teachers' beliefs have been found to impede teachers from carrying out instruction (Lumpe et al., 2000; Yerrick et al., 1997). For example, limited resources available to teachers can hinder their ability to apply technology in instruction even if the teachers strongly believe technology is the best method for a certain lesson. In addition, teachers may not follow their beliefs if they feel pressured by systems of accountability (Yerrick et al., 1997).

Many instruments have been used to measure teacher beliefs in the context of science (e.g., Lederman et al., 2002; Luft & Roehrig, 2007; Lumpe et al., 2000; Sampson et al., 2013; Smith et al., 2013). The instruments summarized in the literature review have specifically addressed science instructional beliefs. However, many of the instruments showed design limitations, as well as specific aspects that did not align with the parameters of this study. The instrument deemed most appropriate for this study was the TBEST questionnaire (Smith et al., 2014).

The TBEST instrument provides a focused measurement of teacher beliefs about science instruction. More specifically, the TBEST shows how beliefs align with three elements related to teaching the subject of science: (a) Learning Theory science instruction, (b) Confirmatory science instruction, and (c) all hands-on, all the time science instruction. Items on the TBEST that address Learning Theory science instruction are based on the recommended aspects of science pedagogy described by Banilower et al. (2010; i.e., motivating, surfacing prior knowledge, engaging with phenomena, using evidence, and sense-making). Confirmatory science instruction items are instructional activities used to support student learning that has already occurred (Smith et al., 2014). All hands-on, all the time science instruction refers to hands-on activities used without the end goal of relevant student learning (Smith et al., 2014). Ideally, responses on the TBEST would converge with Learning Theory science instruction items and diverge from items that reflect both Confirmatory science instruction and all hands-on, all the time science instruction (Smith et al., 2014).

The effectiveness of instructional practices in classrooms is measured using multiple accountability assessments, one of which is the ACT. The ACT is an assessment taken by most students during their secondary school years that has the predictive power to indicate college and career readiness (Allen & Sconing, 2005; Camara, O'Connor, Mattern, & Hanson, 2015; Mattern et al., 2015). The ACT is divided into four subtests: English, math, reading, and science. The ACT Science portion assesses students on their ability to reason and analyze data within the context of science content (ACT, Inc., 2014).

Chapter II is an exploration of the literature that served as a foundation for this study. The beginning of the chapter focuses on linking teachers' beliefs with their instructional practices. This section provides justification for the use of the TBEST questionnaire for this study. Responses from the TBEST are a reflection of teacher beliefs. By linking beliefs with instructional practices, the researcher was able to include a much larger sample size. The second section of Chapter II addresses the concepts of science pedagogy, NOS, and PCK. Synthesis of these concepts provides a deeper overview of the kind of effective science instruction that can lead to higher academic achievement. The chapter concludes with an overview of the ACT, specifically the science section. This section highlights the importance of the ACT assessment and validates its use for measuring college and career readiness as well as its use as an accountability factor for measuring effective science instruction.

Statement of Problem

The ACT Science assessment focuses on students' ability to reason and conduct data analysis in a science context. Answering questions correctly on the assessment, however, does not depend on content knowledge. Preparation focused on science content alone will not prepare students adequately for ACT Science (ACT, Inc., 2014). Instead, instruction that includes aspects of Learning Theory measured in the TBEST (i.e, motivating, surfacing prior knowledge, engaging with phenomena, using evidence, and sense-making), NOS, and the specific course content provide the means necessary to prepare students for ACT Science. Systematically preparing students for ACT Science over several school years requires a planned progression of academic development. As a result, science teachers must have a unified outlook on effective instructional practices that prepare students for ACT Science.

At the time of this study, the school district participating in this study was in the process of improving student performance on the ACT. The school district, however, did not have a baseline to identify the science instructional practices taking place in classrooms. The school district also did not have evidence of a unified effort to address ACT Science among teachers in school science departments. This study involved collecting data on the beliefs of teachers about science instruction in order to provide an understanding of both the instruction taking place in science classrooms and the extent to which teachers' beliefs were unified regarding perceptions of instructional practice. The measurement of aligned beliefs was used as evidence of science departments working collectively to provide unified instruction over several school years leading up to the ACT assessment. Further, student scores on the ACT were collected from the participating schools to determine potential relationships between ACT Science and the instructional beliefs regarding Learning Theory and aligned instructional beliefs.

The measurement of the relationship between teacher beliefs about science and academic performance on the ACT Science test has been excluded from current literature, especially within the context of a single school district. This study on teacher beliefs and ACT Science performance helps fill a void in education literature and contribute to an ongoing discussion on improving ACT Science achievement.

Purpose of the Research

The purpose of this study was to build a foundation for measuring science teacher beliefs about instruction, determine the alignment of these beliefs among teachers within single science departments and between schools in the school district, and identify existing relationships between science instructional beliefs and student achievement on the ACT Science test. Belief instruments such as the TBEST questionnaire are often used to measure the results of a professional development or training effort (e.g., Lederman et al., 2002; Luft & Roehrig, 2007; Lumpe et al., 2000; Sampson et al., 2013; Smith et al., 2014). The TBEST was originally designed to determine the value of a professional development effort (Smith et al., 2014). Although in this study, the researcher did not provide a specific professional development session, the TBEST was used to measure teacher beliefs about science instruction. Thus, the TBEST served as a foundational instrument intended to gather baseline data on teacher beliefs about science instruction. As science instruction improves, the TBEST instrument can be used to determine the perceptions of both individuals and groups regarding science instruction. The findings from this study can provide insight into progress being made toward aligning instruction with efforts to improve ACT achievement.

Collective instructional efforts among teachers, rather than the work of a single teacher, are more likely to lead to increased student achievement on the ACT (Dufour, Dufour, & Eaker, 2010; Earkens et al., 2008). Students often have multiple science teachers during secondary school prior to taking the ACT (e.g., physical science teacher, biology teacher, chemistry teacher). This means that students have multiple instructional influences that guide them through science courses. Identifying the science instruction practices of these teachers through the TBEST will provide an outlook on the instructional experiences of students prior to the ACT.

Gathering and analyzing data on science instruction and its relationship with ACT achievement may benefit the school district and participating schools by

1. Providing insight into teacher beliefs and the alignment of those beliefs with concepts explored with the TBEST questionnaire (i.e., Learning Theory instruction, Confirmatory instruction, and All Hands-on All the Time instruction);

2. Providing insight into alignment of instructional beliefs about science among colleagues in the same school science department;
3. Providing insight into alignment of instructional beliefs about science among colleagues at four schools in one school district; and
4. Providing insight into existing relationships between ACT achievement and specific beliefs about science instruction measured by the TBEST questionnaire.

Research Questions

The following research questions guided this study:

1. Do teacher beliefs about science instruction align with Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction, as measured by the TBEST questionnaire?
2. Do science teachers in a science department hold the same beliefs about science instruction?
3. Do science teachers at different schools in one school district hold the same beliefs about science instruction?
4. What relationships exist between science departments with higher belief scores compared to Learning Theory and ACT Science scores?

These data sets and analyses provided a foundational outlook that can lead to informed policy and professional development targeting science instruction. Further, the overall methodology of this study may provide other researchers with a unique route to investigating the college and career readiness of students in terms of the science instruction beliefs of teachers.

This study addressed four research questions related to beliefs about science instruction and student academic performance on the ACT Science test. The quantitative nature of the data necessitated hypothesis testing.

The first research question involved an analysis of data produced with the TBEST questionnaire. Research Question 1 was " Do teacher beliefs about science instruction align with Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction, as measured by the TBEST questionnaire?" The TBEST questionnaire was used throughout the study to measure teacher beliefs about science instruction. The instrument consisted of 21 items. Participants rated their agreement with statements on a 6-point scale. Each item was categorized into three different types of instructional alignment: (a) Learning Theory science instruction, (b) Confirmatory science instruction, and (c) All Hands-on All the Time science instruction (Smith et al., 2014). Scores for individuals' responses were tallied, and participants' beliefs were categorized. The characterization of teacher beliefs addressed the first research question by determining how instructional beliefs aligned with each of the three concepts measured by the TBEST.

Research Question 2 was "Do science teachers in a science department hold the same beliefs about science instruction?" Teachers working in a collaborative environment may influence one another and their instructional practices (Dufour et al., 2008). In this study, teachers who worked in a science department collectively prepared students for the

ACT Science assessment. The ACT does not assess curricula from any particular grade level, but rather a culmination of learning gained throughout middle and high school (ACT, Inc., 2016a). The purpose of the second research question was to compare beliefs of teachers who worked in the same science department. Their beliefs were considered a reflection of instructional alignment for students throughout their science courses leading up to the ACT. The answer to this research question provided a deeper understanding regarding how a group of teachers collectively worked to improve student achievement. Data collected from the TBEST were analyzed utilizing descriptive statistics. Variances among responses within schools and variances among the overall population of the study provided the data for the evaluation and discussion of the second research question.

Research Question 3 was "Do science teachers in the same school district hold the same beliefs about science instruction?" The alternative hypothesis for this question reflected an assumption that school teachers in a school district will possess the same beliefs about science instruction. In contrast, the null hypothesis was that science teachers in the same school district hold different beliefs about science instruction. Similar to the second research question, the third research question provided evidence regarding how teachers within a school district can collectively work toward student achievement. Data from the TBEST were used in an ANOVA to analyze the variances within and between science departments in the school district. The ANOVA was followed by a Bonferonni post hoc analysis to determine any significant corrections being measured.

Research Question 4 was "What relationships exist between science departments with higher belief scores compared to Learning Theory and ACT Science scores?" For this question, Learning Theory refers to the measurement of instruction aligned with science Learning Theory as measured by the TBEST questionnaire. The alternative hypothesis for this research question was science departments with beliefs aligned with Learning Theory will have higher ACT Science achieving students. The null hypothesis reflected an assumption that no difference exists between the student ACT Science achievement of schools with beliefs aligned with Learning Theory and schools with beliefs unaligned with Learning Theory. Schools that possessed teachers with beliefs aligned with Learning Theory science instruction should in turn have students demonstrating higher academic performance on ACT Science. The analysis conducted to answer the fourth research question involved comparing data on TBEST beliefs for each science department with student ACT Science scores. The variables of responses to Learning Theory TBEST items and ACT Science scores were statistically analyzed for correlation.

The rationale for this study was to understand teachers' instructional beliefs about science in a southeastern U.S. school district in order to build a foundation for improving student achievement in science. The exploratory (nonexperimental) nature of the study provided a baseline of the status of science teachers' beliefs and showed the alignment of beliefs within science departments. Thus, the findings may provide insight into the relationship between science department instructional beliefs and student ACT Science achievement.

Methodology

All ACT data were collected directly from the participating schools. However, all of the principals did not have the data directly on hand. Thus, the researcher identified and contacted individuals within each school who were able to provide access to the data needed for the study.

Instructional belief data were gathered through an online survey. The survey was constructed with the software program Qualtrics. Participants were given a link to the survey through a recruitment e-mail. The recruitment process took place within a two-week window.

The data collected were analyzed using SPSS (version 23). A variety of statistical analysis were completed, including conducting descriptive statistics, an ANOVA, and correlational tests. For the ANOVA, a Bonferroni post hoc test was used to determine the specific correlations that proved significant.

Scope and Delimitations

The researcher collected data to compare statistically the instructional beliefs among science teachers. Further, the use of multiple schools in the same district facilitated a statistical analysis between the teacher beliefs of different science departments and student ACT Science achievement scores.

The TBEST questionnaire only contains items measuring agreement with three elements: Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction. As a result, all modes of instruction outside these three presented in the TBEST were not within the scope of this study. In addition, the TBEST questionnaire required participants to respond to items within the parameters of a 6-point agreement scale. Thus, any conclusions drawn about the beliefs of participants must by in terms of those individuals' responses of agreement or disagreement to each TBEST item.

The scores generated by the TBEST questionnaire reflected the views of individual teachers working in the participating school district. The data collected on ACT Science scores, however, contained no formal link between teachers and students. As a result, only general conclusions can be drawn about relationships between science instructional beliefs and ACT Science achievement. Measuring the specific progress of secondary school students over three years of science compared to those science teachers' influences on ACT achievement was outside the scope of this study.

The general use of the TBEST as an instrument to collect beliefs data also needs to be addressed. Arguments have been made to link teacher beliefs and the mode in which instruction takes place in the classroom (e.g., Brickhouse, 1990; Cronin-Jones, 1991; Lederman et al., 2002; Luft & Roehrig, 2007; Lumpe et al., 2000; Magnusson et al., 1999; Sampson et al., 2013; Smith et al., 2014; Wong & Luft, 2015; Yerrick et al., 1997). Researchers have also found variables that cause instructional practice to deviate from teacher instructional beliefs (e.g., Yerrick et al., 1996; Lumpe et al., 2000). Because of the conflict between instructional practice and teacher beliefs, conclusions made in this study about science instruction were limited to the existing literature within the field of study. Although teachers may have reported certain beliefs about instruction, it does not necessarily imply their beliefs were being put into instructional practice.

Limitations

Several limitations affected this study's conclusions. First, data collection was limited to the schools that chose to participate in the study. The data were further limited to the teachers who accepted the invitation to participate. Several methods were used to increase the response rates. For example, multiple e-mails were sent with the survey link, a reasonable two-week window was set to accept survey responses, the survey was conducted online rather than with paper and pencil, the department chairs were contacted to push coworkers to participate, a drawing for $25 gift cards included anyone who participated, and the survey took place at the beginning of the school year rather than during a time period when teachers were overly busy. Response sizes were limited by the overall sizes of science departments in the district. The departments generally contained no more than 15 people.

Second, the TBEST questionnaire contained several aspects that limited the study. The measurement of beliefs about science instruction was not the only variable that affected instructional practice. Factors related to resources and time can affect instructional decisions (Yerrick et al., 1997). As a result, the researcher was unable to attribute the findings directly to the instructional practices taking place within science classrooms.

In addition, the TBEST instrument used an arbitrary 6-point agreement scale. This introduced a subjective element to the belief scores of individual participants. The study used responses on the 6-point scale to determine the alignment of beliefs between participants who worked in the same science departments. Because the 6-point scale did not provide specific references, it was up to the participants to interpret the exact meaning of the scale. This limitation may have produced differences in responses.

Table 1

Definition of Terms

Term	Definition
TBEST	Teacher Beliefs about Effective Science Teaching questionnaire; developed to measure teacher instructional beliefs about science instruction (Smith et al., 2014)
Learning Theory instruction	Science instruction based on the work of Banilower et al. (2010); instruction is aligned with motivating, surfacing prior knowledge, engaging with phenomena, using evidence, and sense-making
Confirmatory instruction	Designed tasks that have students reaffirming what they were already taught
All Hands-on All the Time instruction	Concept within the TBEST instrument that describes activity-based pedagogy implemented for the purpose of student engagement, but not necessarily related to the lesson
Motivating	Applying a balance of extrinsic and intrinsic factors leading to gathered interests about content the students are to learn (Banilower et al., 2010)
Surfacing prior knowledge	Taking initial ideas of learners into account in order to confirm or confront preexisting knowledge (Banilower et al., 2010)
Engaging with phenomena	Opportunity for learners to take on the intellectual work to piece evidence together about a specific idea (Banilower et al., 2010)
Using evidence	Supporting and criticizing claims by learners in order to confirm or restructure their cognitive framework (Banilower et al., 2010); process contributing to science literacy and experiencing the nature of science (National Research Council, 2003)
Sense-making	Opportunity in which learners can make sense of their new experiences; can lead to readjusting cognitive framework in order to account for prior knowledge before new experiences (Banilower et al., 2010; National Research Council, 2003)
Nature of science	The epistemology of knowledge derived from science activities (Lederman, 2006)
ACT	College and career readiness assessment with four parts: English, math, reading, and science
Secondary school	School that serves students in grades 9 through 12
Pedagogical content knowledge (PCK)	Term derived by Shulman (1986) to account for the professional skill set needed by teachers with the discipline of education; the knowledge required to instruct subject matter of a specific content domain (Magnusson et al., 1999)

Organization of the Dissertation

This dissertation began with the opening chapter introducing the study. Chapter II contains a review of research literature relevant to this study. The research includes aspects on linking beliefs and instructional practices, pedagogical content knowledge, and the ACT assessment.

Chapter III covers the methodology used for the study. The chapter details the population in the study, the instrument used, the data collected, the timeline of the study, and the analysis methods conducted.

Chapter IV provides the results and analysis of the data collected from the TBEST questionnaire and ACT Science achievement scores. The chapter complements the methodology described in Chapter III and lays a foundation for the discussion of results in Chapter V.

Chapter V synthesizes the results found in Chapter IV into an explanation of the overall findings. Chapter V also serves as the conclusion to the dissertation, providing implications of the study, based on the results, as well as recommendations for practice and future research.

CHAPTER II

LITERATURE REVIEW

Introduction

This chapter provides a literary background and argument for the current study. In this chapter, the researcher explores the connection between teacher beliefs and classroom instruction. Further, the art of science instruction is investigated, including an analysis of science content, pedagogical practices, and how the two concepts combine to produce science pedagogical content knowledge (PCK). Finally, the ACT is discussed, with a focus on the science subsection.

This study emerged from a school district's need to improve ACT scores. Student achievement on the ACT is based on scores from four subsections: English, math, reading, and science. The science section in particular is not a test of content knowledge but rather of the skill sets related to logic and reasoning within the context of science. A common factor addressed in the effort to improve these skill sets is science classroom instruction. To improve skill sets, teachers must align their instruction with what best promotes science learning for students.

In this study, the researcher sought to provide a baseline of knowledge about the science instruction taking place in classrooms in a single school district. In previous research, this measurement has often been made using classroom observations. However, a more practical mode of measurement was needed for collecting instructional information about a large group of teachers. The Beliefs about Effective Science

Teaching (TBEST) questionnaire was identified as an instrument capable of such measurement (Smith et al., 2014). Using the instrument, however, required a literary foundation connecting beliefs with instruction.

Chapter II is organized into three sections: a discussion of the link between classroom instruction and teacher beliefs, a review of pedagogical content knowledge, and an overview of the ACT. Linking instruction to beliefs addresses how teacher beliefs correlate with science instruction, how teachers can change beliefs, how resources within the environment affect the ability to align beliefs with instruction, and how instruments can measure the beliefs of teachers. The next section involves pedagogical content knowledge (PCK) and specific instruction in science classrooms. The section indicates the development of PCK, the components that make up PCK, pedagogical knowledge, and the science knowledge of teachers. The science knowledge of teachers is explored through the concept of nature of science. This concept forms the epistemological roots of science knowledge (Lederman, 2006). The final section of the chapter addresses the relevancy of the ACT assessment for students, specifically focusing on the ACT Science subtest. The section includes discussions of the alignment of secondary education with the ACT, factors associated with ACT performance, and the purpose of students planning ahead for college and career.

Teacher Beliefs and Science Instruction

Teacher beliefs and the influence of teacher beliefs on classroom instruction constitute a pertinent discussion in education and science reform. Top-down reform policies that do not account for science teachers' beliefs are unlikely to lead to change in science instruction (Lump, Haney, & Czerniak, 2000). Leaders should account for teacher beliefs when undertaking reforms; in addition, teachers should take responsibility for their own beliefs. If teachers understand their own beliefs, they can gain insight into the factors that influence their instructional decisions (Cronin-Jones, 1991). Because belief systems influence instruction (e.g., Brickhouse, 1990; Cronin-Jones, 1991; Lederman et al., 2002; Luft & Roehrig, 2007; Lumpe et al., 2000; Magnusson et al., 1999; Sampson et al., 2013; Smith et al., 2014; Wong & Luft, 2015; Yerrick et al., 1997), understanding personal beliefs can provide teachers with the agency necessary to improve their craft systematically.

Literature presented in this chapter includes 10 studies and instruments that link teacher beliefs to instructional practices (e.g., Brickhouse, 1990; Cronin-Jones, 1991; Lederman et al., 2002; Luft & Roehrig, 2007; Lumpe et al., 2000; Magnusson et al., 1999; Sampson et al., 2013; Smith et al., 2014; Wong & Luft, 2015; Yerrick et al., 1997). The beliefs linked to instruction are not only about pedagogy, but can also be linked to beliefs about the science discipline (Brickhouse, 1990). These researchers have highlighted the importance of properly developing belief systems (Brickhouse, 1990; Magnusson et al.,1999) and revealed the difficulty in changing beliefs later on in an individual's career (Yerrick et al., 1997).

Linking Beliefs and Science Instruction

The 10 studies about teacher beliefs and belief instruments in the literature review all focus on science instruction. For example, Brickhouse (1990) conducted a study with three teachers consisting of interviews and instructional observations. The study specifically focused on how teachers perceived science knowledge to be constructed versus the actual nature of science. Brickhouse concluded that the alignment of personal beliefs with the nature of science influenced science instruction. Teachers who demonstrated beliefs aligned with the nature of science were observed to have more effective instructional practices (Brickhouse, 1990). For these teachers, science was instructed as a socially constructed discipline, in contrast to teachers with beliefs unaligned with the nature of science. Teachers with beliefs unaligned with the nature of science taught science as a linear process and a series of absolute concepts rather than as a theory-based process (Brickhouse, 1990).

Magnusson et al. (1999) confirmed Brickhouse's conclusions in a discussion of the influence of thought processes on science instruction. The researchers described the need for science teachers to take on the three roles of teacher, science educator, and science teacher researcher. In these roles, science teachers must develop beliefs about teaching science, creating science curricula, designing approaches to address specific student understanding, implementing assessment, and creating instructional strategies (Magnusson et al., 1999). Magnusson et al. succeeded in displaying the relationship between instruction and teacher belief systems.

Highlighting aspects of this belief system, Yerrick et al. (1997) studied teachers' beliefs about science curricula and assessment. The researchers found many participants viewed science as a linear, factual, concept-based discipline. In a qualitative study, Yerrick et al. provided participants with a professional development session geared toward science instruction. Yerrick et al. analyzed the effect of the professional development through pre- and postinterviews, a video analysis of teachers collaborating, and artifacts collected from classrooms (e.g., assessments, lesson plans). Yerrick et al. concluded their professional development intervention was not powerful enough to overcome the strength of the beliefs that teachers held coming into the study. Participants demonstrated resistance to change, relying on instructional practices from already established belief systems (Yerrick et al., 1997). Yerrick et al. (1997) attributed teachers' resistance to changing beliefs to many external factors: policy, new teacher training, teacher education programs, accountability factors, high-stakes assessments, collaboration, and existing expectations. Yerrick et al. specifically addressed accountability models as a top-down variable that dominated belief systems for the average teacher. Top-down refers to the implementation of policy, in this case accountability systems, by leaders of an education system.

In contrast, a factor contributing to changing beliefs and instructional practices was the self-efficacy of teachers (Lumpe et al., 2000). Self-efficacy is the belief an individual possesses about his or her ability to carry out tasks in order to produce a desired result (Bandura, 1997). Lumpe et al. studied a group of teachers who identified their environment as unsupportive of best instructional practices. Teachers with high self-efficacy recognized the unsupportive nature of the environment, but did not see it as a deterrent to providing high-quality instruction (Lumpe et al., 2000).

In addition to teachers' belief in their own abilities, the beliefs about student abilities and potential outcomes can affect classroom instruction (Cronin-Jones, 1991). Cronin-Jones found curricula were best implemented when teachers held positive beliefs about student abilities and probabilities for success. Cronin-Jones identified a need for teachers to analyze personal belief systems. After such an exercise, teachers gained insight into their role in the classroom, learned how students learn, and understood their own attitudes toward curricula. Developing this self-awareness promoted teachers' self-efficacy in their ability to deliver instruction effectively.

Wong and Luft (2015) expanded on the notion of self-efficacy with a study concerning why teachers decided to stay in or leave the education profession. Wong and Luft used semistructured interviews and two case studies. The results showed that possessing student- or teacher-centered beliefs could affect whether a teacher stayed in or left the education occupation (Wong & Luft, 2015). Teachers with student-centered beliefs were associated with remaining in the education profession; teachers with teacher-centered beliefs were associated with leaving the education profession (Wong & Luft, 2015). Wong and Luft attributed teachers' belief systems to personal experiences received as a student. Those who received learning experiences under teachers with student-centered beliefs held similar belief systems (Wong & Luft, 2015). Further, the study validated the strength and resistance to change of belief systems found by Yerrick et al. (1997). Teachers held onto the belief systems developed through their own experiences as students, especially when placed in positions without proper mentoring systems in place (Wong & Luft, 2015).

Changing Teacher Beliefs about Instruction

When considering the influence of beliefs on instruction, it is appropriate to discuss how teachers' belief systems can change over time. Luft and Roehrig (2007) concluded that because beliefs can be modified over time, holding “incorrect” beliefs throughout a career in education is not detrimental. Luft and Roehrig conducted semistructured interviews, probing teachers about their beliefs. This methodology strengthened their ability to get as close as possible to true interpretations of teacher beliefs. Observational data of teacher instruction was intentionally not collected to avoid bias when measuring teacher belief systems (Luft & Roehrig, 2007). With the proper support in place, Luft and Roehrig discovered that teachers were able to move from teacher-centered to student-centered belief systems. However, if those support variables were not in place, teachers displayed a tendency to move toward more traditional ideology, which included instructing without accounting for the individual needs of students (Luft & Roehrig, 2007). Luft and Roehrig also found teachers in their study showed signs of resisting change. This resistance resulted in a slow process of changing beliefs (Luft & Roehrig, 2007).

Luft (2001) observed this resistance in an earlier study. In this earlier study, teachers were differentiated by their experience level. An inquiry-based professional development session was conducted with teachers while measuring their instructional beliefs (Luft, 2001). Luft observed new teachers displayed more willingness to change beliefs than did experienced teachers. However, even without changing beliefs, the experienced teachers demonstrated a greater ability to apply the professional development training effectively, compared to new teachers (Luft, 2001). Luft concluded that experience enabled teachers to implement new instructional strategies more easily, but teachers new to education could be guided to shape personal beliefs for the long term.

Similarly, Yerrick et al. (1997) described teachers' buffer of resistance to reforming beliefs. Teachers experiencing new situations showed a tendency to enter scenarios without an open mind; the result was a long, difficult process of changing beliefs (Yerrick et al., 1997).

In a more recent study, Wong and Luft (2015) found this resistance to changing beliefs to be more stable and less malleable. Their conclusions came as a response to studies, including some of their own, in which the authors had claimed otherwise (e.g., Luft, 2001; Luft & Patterson, 2002; Luft, Roehrig, & Patterson, 2003; Simmons et al., 1999). Wong and Luft's study took place over five years; their findings showed little fluctuation in teacher beliefs. One important observation was the absence of or inadequacy of training programs for teachers, especially those new to the profession (Wong & Luft, 2015). Wong and Luft noticed new teachers naturally moved toward more traditional beliefs and instructional practices and away from a reformed-based student-centered approach. This finding emphasizes the importance of preservice and new teacher training and guidance. This type of training and guidance can be the most influential on shaping belief systems (Yerrick et al., 1997).

Use of Resources in Science Instruction

Belief systems may not be the only influential factor guiding instructional practices. The resources available to teachers can also play a role in teachers' instructional decisions. When resources are not aligned with teacher instructional beliefs, students are affected (Lumpe et al., 2000). This is especially true when teachers do not possess the self-efficacy needed to overcome a lack of resources (Lumpe et al., 2000).

Many different things can be considered classroom resources (e.g., time, space, pencils, paper, technology). Yerrick et al. (1997) discussed curricula resources, specifically textbooks. They argued the curricula in many textbooks were compromised because of a perceptual gap between the authors and teachers. When teachers' beliefs do not align with textbook authors' beliefs, aligning instruction with written curricula can fail (Yerrick et al., 1997). A similar argument can be made regarding technology. However, investing in technology does not mean it will be used with fidelity.

Lee and Luft (2008) explored the importance of teachers developing a knowledge base for using their available resources. Two fronts have emerged in the development of this knowledge. First, teachers need receive training and professional development opportunities to learn how to use available resources (Lee & Luft, 2008). Second, teachers need to have an openness to change belief systems in order to avoid underusing or misusing resources. Lee and Luft identified the type of knowledge developed as domain-specific, falling within the scope of pedagogical content knowledge.

Instruments Used to Measure Teacher Beliefs

Researchers have developed instruments to measure teacher beliefs about science and pedagogy. These instruments have ranged from structured interviews (e.g., Luft & Roehrig, 2007) to quantified questionnaires (e.g., Lederman et al., 2002). Each instrument has benefits and shortcomings. Instruments geared toward interviews provide more depth and accuracy when describing the beliefs of individuals. However, the time duration of the interviewing process limits the number of participants. More quantitative means, such as surveys, for example, facilitate larger numbers to participate; however, the survey items themselves are limited to measuring only a few aspects of individuals' beliefs.

Luft and Roehrig (2007) developed the Teachers' Beliefs Interview (TBI) to explore teachers' beliefs about instruction through semistructured interviews. Luft and Roehrig chose to use the interview process alone, purposefully not triangulating the data with instructional observations. They perceived this as a way to limit bias when conducting interviews. Another instrument, similar to an interview protocol, is the Views of Nature of Science (VNOS) questionnaire. The VNOS questionnaire is an open-ended survey providing prompts about the nature of science (Lederman et al., 2002). Participants' responses to the prompts are analyzed to measure their beliefs. Although the TBI and VNOS are effective in obtaining accurate descriptions of beliefs, they are time-consuming to analyze (Lederman et al., 2002; Luft & Roehrig, 2007).

Examples of instruments that have used quantitative analyses include the Context Beliefs about Teaching Science (CBATS) instrument (Lump, Haney, & Czerniak, 2000), Beliefs About Reformed Science Teaching and Learning (BARSTL) questionnaire (Sampson et al., 2013), and the Teacher Beliefs about Effective Science Teaching (TBEST) questionnaire (Smith et al., 2014). All three instruments collect participant responses on multipoint scales. The CBATS instrument has been used to determine the degree in which environment influences classroom instruction (Lump, Haney, & Czerniak, 2000). In addition, the instrument has been used to gather profiles on the beliefs teachers have about their personal agency (Lump, Haney, & Czerniak, 2000). The BARSTL questionnaire was originally designed as an analysis of elementary teachers, intended to determine the alignment between teacher beliefs and reformed science pedagogy (Sampson et al., 2013). The TBEST questionnaire indicates how teacher beliefs relate to science instruction (Smith et al., 2014). The questionnaire was developed with cognitive science research rather than with any particular science discipline (Smith et al., 2014). Each item focuses on specific science pedagogy (i.e., Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction). The TBEST has been used to determine teachers' alignment with a form of science pedagogy related to these three elements (Smith et al., 2014). The CBATS, BARSTL, and TBEST all produce numeric scores that can be analyzed quantitatively. In addition, these three instruments enable a large number of participants, but are limited to measuring instructional beliefs rather than measuring instruction itself (Lump, Haney, & Czerniak, 2000; Sampson et al., 2013; Smith et al., 2014).

Pedagogical Content Knowledge

The content being taught determines the unique properties of classroom instruction (Shulman, 2015). Teachers gain the skill set of instructing within their discipline through knowledge of the content they are teaching, knowledge of best instructional practices based on Learning Theory, and experience in the field of education (Shulman, 2015). The term *pedagogical content knowledge* (PCK) is used to describe the unique instructional skill sets for specific curricula. This section covers the historical bounds of the concept, components of the concept found in literature, and the broader categories of pedagogy and content that specifically make up science PCK.

Pedagogical content knowledge was conceived to explain what teachers should know and understand as they enter the teaching profession for specific domains of instruction (Shulman, 1986). PCK evolved over time, not only as a new standard for preparing teachers through the development of the National Board for Professional Teaching Standards (Berry, 2007), but also as a policy movement to combat growing concerns by the public about education (Shulman, 2015).

Shulman (1986) summarized his concerns about the public outlook on education by quoting George Bernard Shaw: “He who can, does. He who cannot, teaches” (p. 4) Shulman (2015) described an individual who never trained to become a teacher but passed a teacher certification test without any preparation. Shulman (2015) considered the event an attack on the quality of the teaching profession.

PCK was identified as the answer to the simplistic public outlook and quality issues found in education (Shulman, 2015). Cooper, Loughran, and Berry (2015) summarized the value of PCK for education:

> Perhaps a serious focus on researching the nature and influence of science teacher educators’ PCK might help bolster the teaching profession in new ways and highlight the importance of teacher education as something that develops and supports a profession involved in sophisticated and complex business. (p. 69)

The implications of PCK research range from training teachers to enhancing perspectives of the teaching profession. More specifically, science teachers are pushed to know not only content, but also the specific instructional methods through which science is best taught (Shulman, 2015).

Development of PCK

Education can be viewed in terms of historical phases. Shulman (2015) described two different eras of education. Within the first, teachers focused instruction on content knowledge with little attention paid to pedagogy. The second era of education contained a dramatic shift from focusing on content-driven training to pedagogy-focused training (Shulman, 2015). The gap between the two approaches required a hybrid focus between content and pedagogy (Shulman, 2015). Shulman argues PCK to fill this gap. It does so by consisting of pedagogy focused within a specific content domain.

Pedagogical knowledge has routinely been correlated with quality of instruction. Content knowledge, however, shows a weaker relationship with quality of teaching. The inadequate relationship between content knowledge and teaching quality has led to the rise of PCK (Shulman, 2015).

PCK is defined as the knowledge required to instruct subject matter of a specific content domain (Magnusson et al., 1999). Developing content knowledge (CK) is the starting point to obtaining PCK (Daehler et al., 2015). Knowing content enables teachers to adapt instruction to fit the needs of individual learners (Heller, Daehler, & Kasowitz, 2004; Magnusson et al., 1999). Heller et al. (2004) studied 12 teachers and tracked changes in their CK and PCK over the course of several months. Heller et al. gave teachers six case studies that included an academic task. Teachers were asked to construct responses to explain how they would approach the task and to describe what they perceived students would find difficult about the task (Heller et al., 2004). Teachers were also asked to respond to examples of incorrect student work (Heller et al., 2004). The results showed teachers with weaker CK could not easily construct responses to the cases nor determine student misconceptions when analyzing student work (Heller et al., 2004). These teachers also struggled with creating alternative instructional methods in response to student misconceptions (Heller et al., 2004). In other words, a higher degree of CK was an indicator of teachers with a higher degree of PCK.

Beyond developing PCK in the context of specific content, PCK can also be developed by individuals or within collaborative groups. Smith and Banilower (2015) used the terms *personal PCK* and *canonical PCK*. Personal PCK refers to the development of PCK as individually constructed, and canonical PCK as constructed by a group in which multiple teachers contribute their expertise (Smith & Banilower, 2015). Within canonical PCK, components of content and pedagogy become a set of agreed-upon standards (Smith & Banilower, 2015).

Daehler et al. (2015) drew several fundamental conclusions about the development of PCK in science. First, they believed that science learning and teaching should be interconnected. Teachers should be challenged to analyze science content while coming up with methods to deal with student misconceptions (Daehler et al., 2015). Second, teachers should have access to instructional modeling of high-quality curricula (Daehler et al., 2015). Professional development efforts should provide teachers with instructional methods they could use with specific curricula (Daehler et al., 2015). Third, teachers need to develop a strong sense of CK and science pedagogy (Daehler et al., 2015). Teachers should be challenged with “vexing aspects of science related to a given topic and then [receive] learning opportunities that push teachers to examine these tricky issues first-hand" (Daehler et al., 2015, p. 57). Fourth, collaborative environments should be established to engage in sense-making collectively (Daehler et al., 2015). Teachers need to work together to conquer challenging problems—the problems can deal with science content, pedagogy, or a combination of the two (Daehler et al., 2015). Finally, teachers need to hold teaching to a professional standard: Life-long learning and the pursuit of shaping the craft of instruction through PCK are most important (Daehler et al., 2015).

Components of PCK

PCK is a complicated concept that goes beyond just simply blending content and pedagogical knowledge (Shulman, 2015). The PCK concept continues to evolve along with instruction and content (Shulman, 2015). Teachers are capable of uniquely blending their knowledge of instruction and curricula for their personal classroom context. PCK is both dynamic and continually evolving; however, researchers continue to attempt to conceptualize the components of the term (e.g., Bransford, Brown, & Cocking, 1999; Gess-Newman, 1999; Lee & Luft, 2008; Magnusson et al., 1999).

Many PCK components have been suggested (e.g., Bransford, Brown, & Cocking, 1999; Gess-Newman, 1999; Lee & Luft, 2008; Magnusson et al., 1999). PCK, however, may always contain a degree of uncertainty (Smith & Banilower, 2015). This is because of the evolving concepts of content and pedagogy. Even considering the uncertainty, understanding current components that contribute to PCK can aid in the development of teachers.

Table 2

PCK Components Referenced in Literature

PCK Component	Marks (1990)	Magnusson et al. (1999)	Bransford et al. (1999)	Lee & Luft (2008)
Student understanding	✓	✓	✓	✓
Knowledge and beliefs about science		✓		✓
Curricula		✓		✓
Assessment		✓		✓
Instructional strategies	✓	✓		✓
Goals				✓
Organization				✓
Resources	✓			✓
Subject matter	✓			

Note. PCK is a broad concept for which a single definition is difficult to derive. This difficulty is demonstrated by the number and diversity of suggested components making up PCK.

Within this overview of science PCK literature, approximately nine components of the concept have been presented (Table 2). Some authors have agreed on components; others are alone in their suggestions. The most agreed-upon component of PCK is student understanding (Bransford et al., 1999; Marks, 1990; Magnusson et al., 1999; Lee & Luft, 2008). Bransford et al. (1999) described different aspects of student understanding, including teachers' goal to understand students' prior beliefs about science and their personal context. Knowing students' prior beliefs allows teachers to either build on knowledge or correct misconceptions by providing individualized instruction (Bransford et al., 1999). Students also need to be provided the opportunities to see science in action, explore science concepts, and experience sense-making with their peers (Bransford et al., 1999). These aspects of student understanding parallel other suggested components.

Another commonly suggested PCK component is instructional strategies (Marks, 1990; Magnusson et al., 1999; Lee & Luft, 2008). Marks (1990) suggested instruction can focus on students, presentation, or media. Student-focused instruction contains learning activities that students complete primarily on their own (e.g., homework, assessments; Marks, 1990). Presentation-focused instruction is the organization of teaching, curricula, instructional strategies, and explanations provided to students (Marks, 1990). Finally, the media-focused instruction includes the materials and text used to promote learning (Marks, 1990). Many of the instructional aspects that Marks described have been suggested as individual components of PCK by other researchers. For example, Lee and Luft (2008) identified resources in general as a component. The curricula and assessment have also been identified as individual components (Lee & Luft, 2008; Magnusson et al., 1999).

In addition to Marks's (1990) overview of instructional strategies, the knowledge and beliefs of teachers have been identified as a PCK component (Lee & Luft, 2008; Magnusson et al., 1999). The knowledge and beliefs of teachers includes not only the depth of understanding a teacher has regarding the content being taught, but also the personal perspective a teacher may have about the subject matter (Magnusson et al., 1999).

Other components unique to individuals include goals (Lee & Luft, 2008) and subject matter (Marks, 1990). Lee and Luft (2008) described teachers who plan lessons mindfully toward a particular goal. For example, a goal for students was to improve their ability to identify scientific phenomena occurring in everyday life (Lee & Luft, 2008). Planning around such a goal guided teachers' instructional decisions (Lee & Luft, 2008). On the other hand, Marks (1990) described subject matter as being the purpose behind a lesson. Subject matter represents the justification for why a teacher would cover specific content (Marks, 1990). Focusing on subject matter forces teachers to base their instructional decisions on the most important elements of the content (Marks, 1990).

The components of PCK provide a current conceptual foundation for developing PCK within individuals. The argument of uncertainty regarding PCK, however, still exists (Marks, 1990; Van Driel & Berry, 2010). After conducting a study to determine the structure of PCK, Marks (1990) noted the ambiguity resulting from too many PCK components blending together with PCK itself. Researchers have found difficulty distinguishing between PCK, subject matter knowledge, and pedagogical knowledge (Marks, 1990). Marks suggested another ambiguity involved the idea that some PCK components were discipline-dependent, while others could stretch across multiple disciplines. The blurred line between discipline-dependent components versus those relevant to all education could hinder the development of a common language about PCK (Marks, 1990).

Van Driel and Berry (2010) expressed a similar view regarding the ambiguous PCK concept. They noted that PCK lacked a "universally accepted conceptualization"

(p. 657). PCK was portrayed as knowledge specific to individual content within a discipline. On the other hand, PCK was also portrayed as specific to an entire discipline or even as a universal concept (Van Driel & Berry, 2010).

Smith and Banilower (2015) concluded that overall, PCK remains a formidable construct that is inadequately defined. This uncertainty in the definition of PCK has hindered researchers' attempts to measure it among teachers (Smith & Banilower, 2015; Van Driel & Berry, 2010). Ultimately, this may be the reason why Shulman constructed the National Board for Professional Teaching Standards, which uses portfolios to assess teachers (Berry, 2007). Any form of standardized assessment would not be capable of measuring personal PCK (Smith & Banilower, 2015). The ongoing difficulty in defining PCK has also posed a problem for the progression of PCK literature (Van Driel & Berry, 2010). Because PCK is unique to different subject matter experts (Marks, 1990), advancing PCK research would require the efforts of people in specific disciplines.

PCK and the TBEST Questionnaire

The TBEST questionnaire focuses on science instruction aligned with three categories: Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction (Smith et al., 2014). Learning Theory science instruction comprises the aspects of motivating, surfacing prior knowledge, engaging with phenomena, using evidence, and creating opportunities for sense-making (Banilower et al., 2010). The components of Learning Theory science instruction collectively make up what can be considered a version of science PCK (Banilower et al., 2010).

Motivating involves applying a balance of extrinsic and intrinsic factors that promote interest in presented science content (Banilower et al., 2010). For students to retain learning, they must be motivated to take interest in the presented content (Kesidou & Roseman, 2002). This notion is behaviorist in nature. Motivation to learn can be driven by internal and external factors such as rewards or punishment (Thorndike, 1921; Skinner, 1950). Motivating students is the starting point for the other aspects of Learning Theory science instruction.

Surfacing prior knowledge of students involves learners taking into account their preexisting knowledge about the topic (Banilower et al., 2010). Surfacing prior knowledge forces students to confirm or confront their preexisting cognitive structures (Banilower et al., 2010). This constructivist outlook is rooted in the work of Piaget (2013) and Vygotsky (1980). Students construct new knowledge depending on their observations and relate it back to content already conceived in their personal cognitive structures (Vygotsky, 1980).

The ability to relate content to personal cognitive structures provides the opportunity to engage with new phenomena. Engaging with phenomena allows learners to take on intellectual work to piece together evidence about a specific idea (Banilower et al., 2010). Through this process, students must use evidence to criticize or make claims of their own, thus focusing students to confirm or restructure their cognitive frameworks (Banilower et al., 2010).

Throughout the process of engaging with phenomena and using evidence to restructure cognitive structures, students are acting on their ability to make sense of their observations (Banilower et al., 2010). Sense-making requires an opportunity for students to analyze experiences by formulating conclusions based on prior knowledge and new observations (Banilower et al., 2010). Engaging with phenomena, using evidence, and sense-making can all relate to the concept of active learning (Brown, 1975; Flavell, 1976; Palincsar & Brown, 1983; Scardamalia, Bereiter, & Steinbach, 1983; Schoenfeld, 1991). Active learning largely deals with student metacognition and the ability to predict and monitor learning (Bransford et al., 1999). This ability facilitates the transfer of understanding to new experiences, resulting in the construction of new knowledge (Piaget, 2013).

Instruction focused on the aspects of motivating, surfacing prior knowledge, engaging with phenomena, using evidence, and sense-making have been determined to support learning science concepts most effectively (Banilower et al., 2010). Understanding the pedagogy that best addresses the learning content within a specific discipline is seen as PCK (Shulman, 2015). Understanding how to utilize the components of Learning Theory science instruction offered by Banilower et al. can contribute to a teacher's science PCK.

Pedagogical Knowledge

Aspects of pedagogy in education, especially in the discipline of science, are extensive and continually evolving. However, some underlying themes can guide pedagogy. As mentioned, Banilower et al. (2010) described five elements that should be included in all pedagogy: motivating learners, surfacing prior knowledge, engaging learning with phenomena, using evidence to criticize a claim, and making sense of targeted learning. Banilower et al.'s five aspects are supported throughout the literature (Banilower et al., 2010).

Building on students' prior knowledge requires teachers to recognize what students already understand, to identify student misconceptions that may exist, and to understand their personal context outside the classroom (Banilower et al., 2010). "Learning in science is more a matter of altering prior conceptions than giving explanations where none existed before" (Brickhouse, 1990, p. 60). Students do not arrive as blank slates, but instead have ideas about instructional content. Hashweh (1996) identified building on prior knowledge as the heart of constructivism. In research, constructivists attempt to rely solely on the perspectives of participants (Creswell, 2013). Therefore, a constructivist teacher, according to Hashweh, uses approaches that build on prior conceptions, correct misconceptions, and provide for the needs of students on an individual level. These approaches entail applying effective strategies and designing evolving strategies based on curricula and the individual needs of students (Hashweh, 1996).

Providing for students on an individual level requires an environment without constraints (Brickhouse, 1990). Providing a nonresistant environment allows teachers to align their instruction with their beliefs to best serve their students (Brickhouse, 1990). This environment shifts the administrative focus to training teachers properly and providing the opportunity for them to align beliefs with research and best practices. Brickhouse noted these types of environments have the potential to produce powerful practitioners.

Science Content Knowledge

In education, the identity of science as a discipline is most closely associated with content knowledge alone (Brickhouse, 1990). Nature of Science (NOS) has been recognized for over a century (Central Association of Science and Mathematics Teachers, 1907). However, in the 1950s, the concept began to be promoted through research (Lederman, 2006). Through this research, NOS has evolved over time (American Association for Advancement in Science, 1990; Central Association of Science and Mathematics Teachers, 1907; National Science Teachers Association, 1982). A key shift in the concept of NOS came with the work of Kuhn (1962), who proposed a paradigm shift from thinking through a means of justification to thinking through a means of scientific discovery. This shift allowed NOS to become to a concept concerned with the advancement of science knowledge (Abd-El-Khalick & Lederman, 2010).

Lederman (2006) stressed the importance of distinguishing between NOS and scientific processes or scientific inquiry. At first, Lederman et al. (2002) found it difficult to arrive at a single definition of NOS. Later, Lederman referred to NOS as the "epistemological underpinnings of the activities of science and the characteristics of the resulting knowledge" (Lederman, 2006, p. 3). In other words, the concept of NOS encompasses the dynamic processes and thinking that have produced specific science knowledge.

Students' understanding of NOS depends on classroom instruction (Lederman, 2006). Establishing instruction that incorporates NOS, however, can be challenging. Brickhouse (1990) studied the relationship between content knowledge and teachers' understanding of NOS. Using degrees earned as a measurement of content knowledge, Brickhouse discovered that NOS understanding increased as content knowledge increased. Even prior to Brickhouse's study, Lederman (1986) found that even when teachers understood the concept of NOS, the concept was not fully incorporated into instruction. Further, it may be a mistake to assume most teachers have a grasp on NOS. In summarizing conclusions drawn from the previous five decades of NOS research, Lederman (2006) concluded neither K–12 students nor teachers had adequate conceptions of NOS. Lederman (2006) emphasized reflective instruction as being the best mode of learning NOS, compared to "simply doing science" (p. 5). However, the incorporation of NOS in instruction may conflict with the best interests of teachers concerned with content-driven accountability (Yerrick et al., 1996).

Relationship of PCK, NOS, and Learning Theory Science Instruction

The concepts of PCK, NOS, and Learning Theory science instruction are interrelated and contribute to the landscape of this study. The Learning Theory components measured by the TBEST questionnaire are specific pedagogy that best support learning science content (Banilower et al., 2010). The components include motivating students, surfacing prior knowledge, engaging students with phenomena, using evidence to create and criticize claims, and providing students time to make sense their observations. These components contribute to science PCK, as shown in Figure 1.

Science PCK in this study is a perspective on the pedagogical practices that best support learning science content. The concept of science PCK is a general overview for best practices for all of science rather than for a specific course. This corresponds with the ACT Science test, an assessment that is not rooted in any particular science course, but rather that covers skills that should be developed over the course of students' academic careers.

NOS is a concept similar to science PCK in the sense that it has a place in all science courses. NOS, however, is rooted in science content, where it serves as an explanation for how knowledge is built (Lederman, 2006). NOS also corresponds with each aspect of science Learning Theory science instruction (Banilower et al., 2010). As the aspects of science Learning Theory are applied in a classroom, students are at the least indirectly exposed to the NOS concept in the process of learning new content (Banilower et al., 2010).

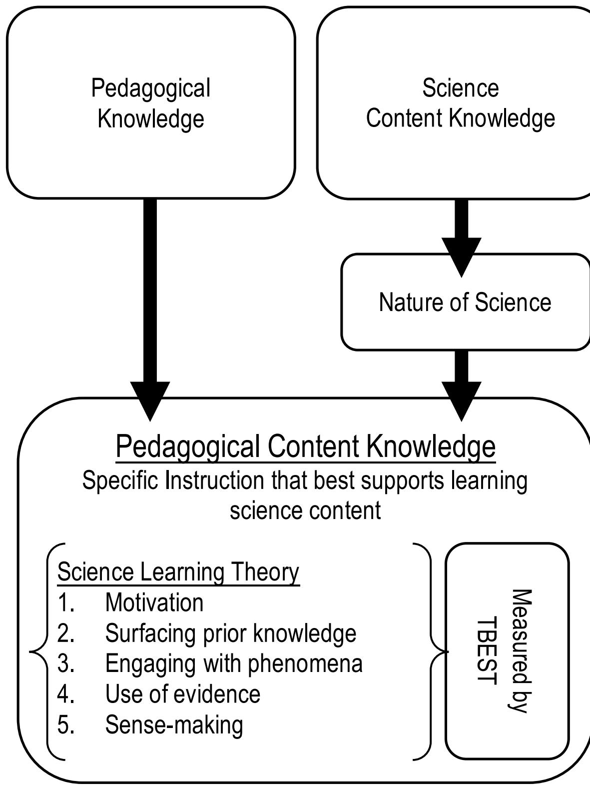

Figure 1. Relationship between PCK, NOS, and science Learning Theory.

Adapted from "Effective science instruction: What does research tell us?" by E. Banilower, K. Cohen, J. Pasley, and I. Weiss, 2010, *Center on Instruction*; "Those who understand: Knowledge growth in teaching," by L. S. Shulman, 2015, *Educational Researcher*, *15*(2); "Situating beliefs in the theory of planned behavior: The development of the teacher beliefs about effective science teaching questionnaire," by P.S. Smith, A. A. Smith, and E. R. Banilower, 2014; "Research on nature of science: Reflections on the past, anticipations of the future" by N. G. Lederman, *Asia-Pacific Forum on Science Learning and Teaching*, *7*(1), 2.

NOS can also be treated as content within a specific science course. This goal requires specific instruction exposing students to knowledge of how a course was built over time through experiments and theory (Lederman, 2006). Instructionally, teachers would benefit from learning a more specific PCK rather than the general science PCK proposed in this study. Addressing the concept of NOS in this way serves as an example of what Lederman (2006) suggested was absent in science classrooms. In addition, the specific course PCK required to present the NOS concept is an example of Shulman's (2015) vision for the PCK concept, designed to explore the depths of individual disciplines.

ACT

The ACT is a test that has consistently grown in popularity as a component of college applications and accountability measurement in secondary education (ACT, Inc., 2016b). The test comprises four subjects: English, math, reading, and science. Erickson (2015) provided a description of the test:

> ACT has proposed a multidimensional model of college and career readiness that takes into account much more than just core academic skills. Also included are the student's behavioral skills, career navigational skills, and important abilities like critical thinking, collaboration, and problem solving (as quoted in ACT Annual Report, 2015, p. 3).

As implied, the purpose of the ACT lies in the measurement of skill sets needed for college and career readiness. Depending on the student, this purpose encompasses a wide range of meaning. The purpose also requires the assessment to measure a wide range of knowledge and skill sets.

Each test in the ACT can be distilled into the skill sets it measures. The science test consists of 40 questions and is 35 minutes in duration (ACT, Inc., 2016a). The test assesses students' ability to interpret data, interpret scientific investigations, evaluate scientific models, draw inferences, and analyze experimental results (ACT, Inc., 2016a).

The interpretation of data and scientific investigations consists of questions related to analyzing and manipulating experimental data from diagrams, tables, and graphs while addressing the design, instruments, and procedures of experiments (ACT, Inc., 2014). Test questions dealing with the evaluation of models, inferences, and results of experiments require students to draw conclusions and make predictions about scientific information presented in a data set or from an experimental theory (ACT, Inc., 2014).

The ACT Science test format addresses a knowledge base beyond the content knowledge of any particular discipline. The test offers a measurement related directly to NOS. In the next section of this paper, the ACT Science test is discussed, thus providing a rationale for exploring the relationship between classroom instruction and student achievement. Further, the section incorporates research published by ACT to address student achievement in both coursework and the ACT, factors and trends that affect ACT achievement, and what ACT achievement means for students planning for college and career.

ACT Assessment and Secondary Education

The alignment between the ACT and courses in secondary education instruction is not always clear. The ACT is a college readiness exam. Secondary education instruction is designed to prepare students for college, but this instruction occurs in addition to many other student responsibilities. Instruction is largely content-driven and not reflective of the skill sets the ACT assesses. Yet, the challenge remains to prepare secondary students for the ACT and college and career readiness. Finding the instructional means to do so is not always clear for teachers and schools. This section addresses some of the factors involved in providing instruction in relation to the ACT and the predictive power of both for the future success of students.

Allen and Sconing (2005) investigated grades achieved by students in college English, mathematics, social science, and science courses. They compared the grades with the students' corresponding ACT test scores. The science results indicated 80% of students who scored a 24 on the ACT Science test earned at least a B in college biology (Allen & Sconing, 2005). These results, however, did not characterize the ACT as an assessment with predictive capabilities for individual courses (Allen & Sconing, 2005).

Mattern et al. (2015) addressed the predictive nature of the ACT for courses in science, technology, engineering, and mathematics (STEM). They found the ACT was a better indicator of whether students were prepared for college, compared to any specific course. Mattern et al. recognized that even though a particular ACT score did not predict any type of performance in STEM, students who were prepared for STEM college courses scored well on the ACT. This promoted a discussion on the preparation needed for college and career within high schools.

The time spent studying for high school courses correlated with grade point average (GPA), but was not correlated with scores on the ACT (Allen, Robbins, Casillas, & Oh, 2008; McNeish et al., 2015). This finding could indicate secondary-level educators may be too focused on content knowledge, excluding the skill sets students need for college. The argument here is similar to Lederman's (2015) argument that science education focuses on content rather than on NOS.

Casillas, Way, and Burrus (2015) suggested that many measurements of college readiness have issues with validity. After analyzing the literature, Casillas et al. concluded that students' behavioral characteristics (e.g., engagement, participating in classroom discussions, procrastination) were a better indicator of college readiness than were ACT scores or GPA. Classroom grading systems may need to be aligned with the skill sets needed to be college and career ready (Casillas et al, 2015). The difficulty lies in making these instructional changes while maintaining a content-driven classroom.

Although the ACT may not specifically address how to make these instructional changes, the assessment does take a holistic approach to assessing college and career preparation (Camara et al., 2015). As a result, the ACT is one of the better measurements of college and career readiness, even if it is not the best indicator (Camera et al., 2015).

Factors Associated with ACT Scores

Many variables have been analyzed as predictors of ACT achievement (Harmston & Pliska, 2001; Mattern & Radunzel, 2015; McNeish, Radunzel, & Sanchez, 2015). McNeish et al. (2015) categorized these variables as cognitive and noncognitive. The term *cognitive* describes the academic means contributing to achievement, and the term *noncognitive* includes students' characteristics and environments (McNeish et al., 2015). This section addresses specific variables that could be considered predictors of ACT performance.

McNeish et al. (2015) conducted a study using data from the 2012 ACT and an online survey about students' experiences in high school and in their environments (e.g., studying, achieving goals, relating with parents). The primary focus of the study was on noncognitive predictors of ACT scores for characteristics beyond those traditionally studied (McNeish et al., 2015). In particular, McNeish et al. focused on the noncognitive variables of parent involvement, behaviors, goals, and self-perception. High school GPA accounted for the most variance within the composite ACT scores (31%; McNeish et al., 2015). GPA accounted for 23% of the variance for the ACT Science test; noncognitive characteristics accounted for 6% of the variance for composite scores and 4% for science scores (McNeish et al., 2015). When comparing cognitive (e.g., GPA, courses taken, advanced coursework) versus noncognitive variables (e.g., school characteristics, demographics), McNeish et al. found the majority of the variance in ACT performance was attributable to cognitive variables (43% for composite scores, and 34% for science scores). Noncognitive variables accounted for 18% of the variance for composite scores and 15% for science scores (McNeish et al., 2015). Overall, McNeish et al. demonstrated that both cognitive and noncognitive variables influenced ACT achievement. Although the majority of variances were attributable to cognitive variables, it was not enough to isolate ACT performance to only academics—noncognitive characteristics should be accounted for as well (McNeish et al, 2015).

The results of McNeish et al. (2015) confirmed those of an early study by Harmston and Pliska (2001). Harmston and Pliska (2001) analyzed ACT results from five different schools over five years with a focus on the ACT math and science tests. Over the course of the study, little improvement was demonstrated on either test (Harmston & Pliska, 2001). However, their analysis discovered a large difference in mean scores favoring those students taking college preparatory courses (Harmston & Pliska, 2001).

Those students scored 2.9 to 3.3 points higher for ACT math and 2.1 to 2.5 points higher for ACT science (Harmston & Pliska, 2001). Courses designed to prepare students for college are generally regarded as more rigorous in nature. It is reasonable to consider the instruction in the two different types of courses as a contributing factor to both rigor and ACT performance.

The preparation for college programs is becoming increasingly important, especially for first-year college students pursuing STEM degrees (Mattern et al., 2015). These students start their math and science courses immediately upon entering college. Mattern et al. (2015) found 54% of students pursuing STEM majors took chemistry their freshman year, followed by biology (31%), and engineering (23%; Mattern et al., 2015). Nearly half of STEM students in the study took multiple math and science courses throughout their first year (Mattern et al., 2015).

Accounting for both the ACT scores and course grades of the first year STEM students, Mattern et al. (2015) used their study to set benchmarks for STEM readiness. Success was defined as a B or higher in student coursework (Mattern et al., 2015). The results of the ACT for the math and science tests were studied concurrently with first-year calculus, chemistry, biology, physics, and engineering (Mattern et al., 2015). For the science courses, Mattern et al. found 49% of the students earned at least a B; among those 49%, the average ACT Science score was 25.

Mattern et al. (2015) tested the predictive power of a benchmark score of 25 on the ACT Science through a longitudinal study. Their study included graduates with bachelor’s degrees in STEM fields with GPAs of at least a 3.0 (i.e., B average for course grades). Of the students who met both criteria, 77% met the ACT Science benchmark (Mattern et al., 2015). However, Mattern et al. noted that the population size greatly decreased between first-year and fourth-year STEM students. Mattern et al. also studied STEM-major retention over the span of a four-year degree. Students who met the ACT benchmarks of 27 for math and 25 for science were more likely to remain in STEM majors and enroll at the university (Mattern et al., 2015). Meeting the science benchmark meant the chances of earning a STEM degree nearly doubled (Mattern et al., 2015).

These studies show the need to prepare secondary students interested in science. This preparation can be tied to ACT performance, which has predictive power for the academic success of students (Mattern et al., 2015). When preparing students for the ACT, it is important for educators to focus on cognitive factors such as student GPA and courses taken (Mattern et al., 2015). But also of importance are noncognitive factors such as parent involvement, student goals, demographics, and self-perception (McNeish et al., 2015). Together cognitive and noncognitive variables contributed to 77% of the variance in ACT performance (McNeish et al., 2015).

Results from ACT Science also suggest course progression factors into achievement (ACT, Inc., 2013; 2015). Students who took physics as part of their science course progression scored better on average than students who did not have physics as part of their high school curriculum (ACT, Inc., 2013). This is also true of students who took a more rigorous course progression through high school (ACT, Inc., 2015).

Planning Ahead for College and Career

Studies on ACT achievement have demonstrated the value of planning ahead for college and career (e.g., Bobeck & Zhao, 2015; Harmston & Pliska, 2001; Mattern & Radunzel, 2015; McNeish et al., 2015). Students who know what they want to study and who have future goals have been found to score higher on the ACT (McNeish et al., 2015). However, school counselors find it difficult to help students set goals in addition to fulfilling other counseling responsibilities (American School Counselor Association as cited in Bobek & Zhao, 2015). This factor led to only 67% of students enrolling in college out of the 90% with aspirations (U.S. Department of Education, 2006).

Bobek and Zhao (2015) argued a worldly outlook and understanding of existing career fields enhances long-term student success. Students with this understanding make decisions aligned with interests, motivating them to continue their education (Bobek & Zhao, 2015). Bobek and Zhao found this was true not only for students, but also for professionals in their careers. Bobek and Zhao claimed that students and professionals pursuing their interests will have more confidence in personal performance. Similarly, Mattern and Radunzel (2015) argued students who define their career paths and education ambitions are more likely to achieve higher degrees of education. The same concept was proven true for ACT performance (Harmston & Pliska, 2001). Students who indicated plans to pursue a STEM field prior to the ACT math and science tests outperformed others who indicated interest in other career paths (Harmston & Pliska, 2001).

Summary

Chapter II focused on current literature to provide context, to address assumptions, and to justify the need for this study. The argument for the study centered on improving science instruction to prepare students for college and career. One of the primary, widely accepted modes for measuring college and career readiness is the ACT. In this chapter, the ACT assessment was addressed specifically from the context of science, linking variables such as secondary classroom instruction, factors correlated with ACT performance, and the mindset of students in relation to the purpose of the test: assessing college and career readiness.

Success on the ACT Science test has been linked to the preparation of students in the classroom (Harmston & Pliska, 2001; Mattern & Radunzel, 2015; McNeish et al., 2015). This idea was addressed through a discussion of PCK. The chapter showed the importance of providing instruction aligned to PCK, showed how teachers develop and utilize PCK, and covered the fundamentals of pedagogical knowledge and science knowledge. The discussion of science knowledge focused on the need for science teachers to move toward instruction based on NOS. The NOS concept supports the notion of implementing PCK in science classrooms (Banilower et al., 2010; Lederman, 2006, Shulman, 2015).

A beliefs instrument was determined to be the best instrument to measure instruction. The assumption required to apply this instrument was that teacher beliefs would align with instruction. This assumption, according to literature (e.g., Luft, 2001; Luft et al., 2003; Luft & Patterson, 2002; Luft & Roehrig, 2007; Simmons et al., 1999), may not always hold true because of variables of restraint within education. Further, several beliefs instruments were discussed to provide context for the study.

CHAPTER III

METHODOLOGY

Introduction

The methodology of this study was designed to collect data on teacher instructional beliefs and student performance scores to address the research topic of science instruction and achievement. The data were gathered from the Teachers Beliefs about Effective Science Teaching (TBEST) questionnaire and student scores on the ACT Science assessment. The following research questions guided this study:

1. Do teacher beliefs about science instruction align with Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction as measured by the TBEST questionnaire?
2. Do science teachers in a science department hold the same beliefs about science instruction?
3. Do science teachers at different schools in one school district hold the same beliefs about science instruction?
4. What relationships exist between science departments with higher belief scores on TBEST Learning Theory items and ACT Science achievement?

The research questions are summarized in Figure 2 and Figure 3. The chapter begins with a description of the participants and setting of the research, followed by a discussion of the survey instrument. The protocol for collecting and analyzing data is discussed for each research question. Finally, the limitations to the study are presented.

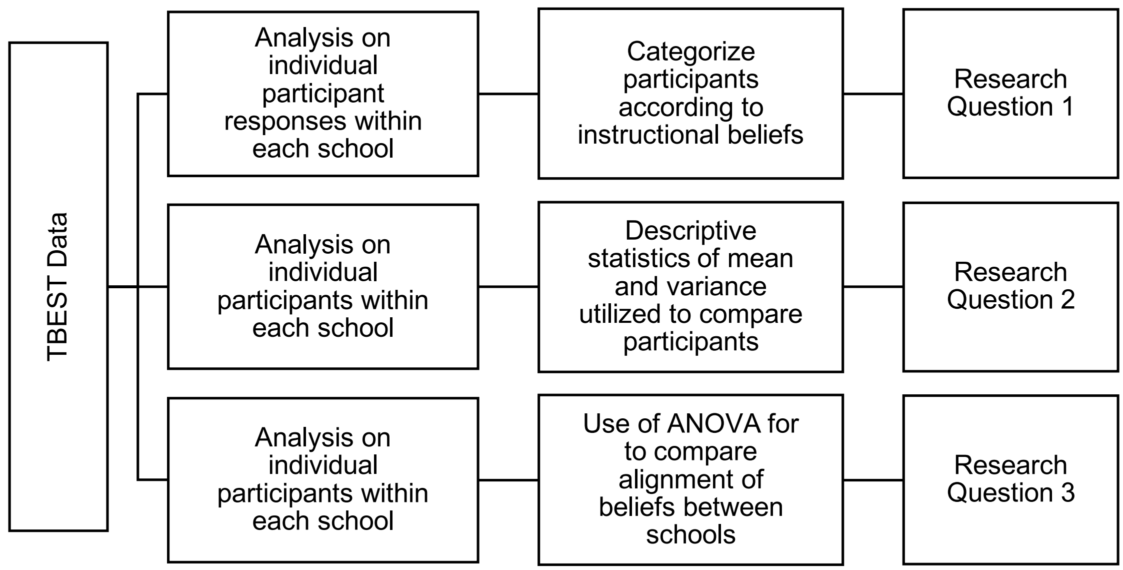

Figure 2. Diagram of data collected for Research Questions 1, 2, and 3.

Participants and Setting

The targeted population was drawn from four high schools in a southeastern school district in the United States. Science teachers working at the four high schools were targeted to participate in the study. In addition, student achievement data of the 2017 graduating class from the ACT Science test were collected from each high school. Recruiting all science teachers except for those hired for the 2017–2018 school year produced valid data for the study. New hires for the 2017–2018 school would have had no impact on assessment scores from years before students started at the school.

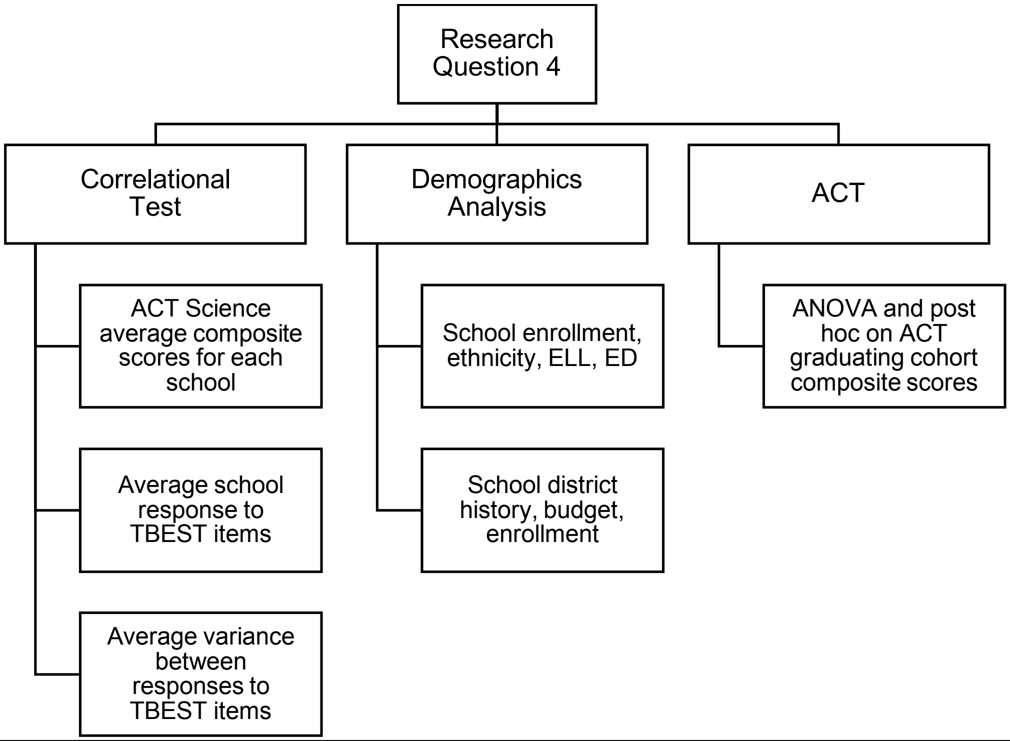

Figure 3. Diagram of data collected for Research Question 4.

Instruments

The survey instrument selected for the study was the Teacher Beliefs about Effective Science Teaching (TBEST) questionnaire (see APPENDIX A: TBEST QUESTIONNAIRE). Smith, Smith, and Banilower (2014) developed the instrument with Horizon Research, Inc. The research behind the instrument involved constructs such as self-efficacy (Riggs & Enochs, 1990), science teaching (Cobern, 2001; Lumpe et al., 2000), nature of science (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002), and science teaching and learning (Sampson & Benton, 2006; Luft & Roehrig, 2007). The TBEST questionnaire includes five elements of instruction: motivating students, building on prior knowledge of students, engaging with phenomena, criticizing claims using evidence, and sense-making (Smith et al., 2014). These elements are independent of pedagogy (Banilower et al., 2010). Because pedagogy can be use effectively or ineffectively, the questionnaire was designed to focus on how students build knowledge and understand science concepts (Smith et al., 2014). The TBEST measures teacher beliefs about instruction in terms of cognitive science literature that contributes to students' understanding (Banilower et al., 2008; National Research Council, 2000).

Development of the TBEST questionnaire took place over a number of phases (Smith et al., 2014). The first phase involved creating items for the questionnaire; the first pilot study included 950 middle school science teachers (Smith et al., 2014). At the end of this phase, the TBEST questionnaire was reduced to 23 items, and the agreement scale was expanded from 4 to 6 points (Smith et al., 2014). The second phase included two more pilot studies; 250 teachers participated in each one (Smith et al., 2014). The questionnaire was reduced to 21 items over three categories of instruction (Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction; Smith et al., 2014).

Next, in the last phase of the TBEST questionnaire's development, Smith et al. (2014) applied a series of validity analyses. The format in which the questionnaire was distributed and the grade levels it utilized were of primary concern (i.e. primary, middle, and high school grade levels). Results using paper-based versus web-based methods confirmed no statistical difference between the two data collection methods (Smith et al., 2014). Over 900 participant responses were used to gauge use with elementary, middle, and high school teachers. The analysis conducted included the chi-square goodness of fit test, the comparative fit index, the Tucker-Lewis index, and the root mean square error of approximation (Smith et al., 2014). No statistical differences were found, thus confirming the instrument could be used across grades K–12 (Smith et al., 2014).

The results derived from the instrument were analyzed to check for the three forms of instruction: Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction (Smith et al., 2014). Distinguishing between the three forms of instruction was accomplished by looking at the level of agreement with each item associated with the factors. Ideally, teachers would have a high agreement with Learning Theory science instruction items while scoring low on Confirmatory and hands-on all the time science instruction items (Smith et al., 2014). Scoring high on Confirmatory science instruction or on All Hands-on All the Time science instruction, or both, would indicate beliefs outside of science Learning Theory. In addition, the pilot study results indicated that belief systems could be aligned with all three instructional factors. Smith et al. (2014) noted alignment with all three factors represented a perspective that all instructional models in moderation can be appropriate for classrooms.

The TBEST questionnaire has provided insight into the science instruction of teachers (Smith et al., 2014). Researchers have used the TBEST questionnaire to describe how beliefs align with instruction (Brickhouse, 1990; Cronin-Jones, 1991; Lederman et al., 2002; Luft & Roehrig, 2007; Lumpe et al., 2000; Magnusson et al., 1999; Sampson et al., 2013; Wong, & Luft, 2015; Yerrick et al., 1997), providing validity for the TBEST instrument. The initial purpose for creating the instrument was to measure the effectiveness of professional development efforts or other treatments designed to influence instructional beliefs (Smith et al., 2014). For the purposes of this study, the TBEST questionnaire was used to determine the instructional beliefs of teachers. The responses of teachers were compared to one another and analyzed for an overall characterization of instruction for each science department and for the school district. Although no treatment was used in this study, the measurements made using the questionnaire were an appropriate use of the instrument.

Design

Data collection occurred during summer and fall, 2016. The TBEST questionnaire (see APPENDIX A: TBEST QUESTIONNAIRE) was distributed online on August 1, 2016, and participants were given approximately two weeks to respond. An initial invitation was sent to all high school science faculty in participating schools. In order to increase response rates, three reminder e-mails were sent containing the hyperlink to the online questionnaire. Potential participants were notified they could be entered in a drawing for one of seven gift cards if they participated in the study. The drawing was not tied to the questionnaire itself; therefore, no e-mail addresses were connected to responses. E-mail addresses were collected with a method different from the one used for the questionnaire.

ACT data collection began during the Summer of 2016 as schools were being recruited for the study. The data collected were the schools' 2015–2016 ACT scores. These scores measured the achievement of students from the 2017 graduating class. The demographics of the student data included gender and race. Upon collection of the survey and ACT data, analysis was conducted using SPSS software version 23.

Survey (TBEST) Data

The TBEST questionnaire was issued online through Qualtrics Software. The e-mails for the gift card drawing were collected using Google Forms. The survey was presented on three pages and encompassed two web domains, as shown in Figure 4. The first page of the questionnaire contained a consent form. Participants consented to participate by clicking on an agreement statement prior to beginning the survey. The second page contained demographic questions. These questions address the status of the participant at their current school.

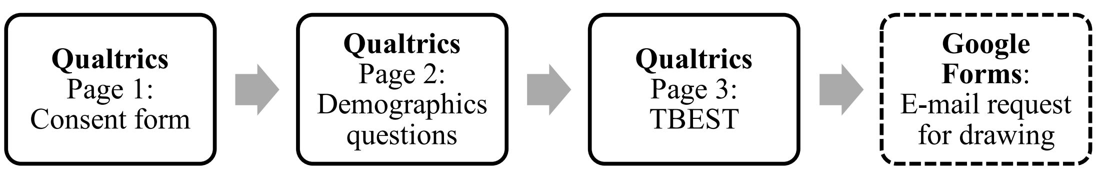

Figure 4. Anonymity assurance of TBEST questionnaire and gift card drawing.
This figure shows the digital layout of the survey instrument used. Two different pieces of software were used to ensure anonymity of participant responses.

Upon completing the questions, participants completed the TBEST questionnaire on the third page. The questionnaire showed 21 items; participants selected a level of agreement for each item. The agreement scale included the following choices: *strongly disagree*, *moderately disagree*, *slightly disagree*, *slightly agree*, *moderately agree*, and *strongly agree*. Upon conclusion of the TBEST questionnaire, participants were prompted with a hyperlink to access the Google Forms survey requesting their e-mail address for the gift card drawing. The e-mail addresses will be drawn at random for winners. At least one individual at each participating school will win a gift card.

ACT Data

The ACT is an assessment consisting of the following subsections: English, math, reading, and science. The focus of this study was the science subsection. The demographics of gender and graduation year were collected with the ACT Science scores. Collecting these data began with contacting the principals at each of the participating schools. After the initial correspondence with each principal, others within the school were contacted based on who managed the ACT data (e.g., guidance counselors, technology coaches, assistant principals). Principals who did not respond to the initial invitation received three additional e-mails inviting them to participate. If the principal did not respond after the fourth attempt of correspondence, the researcher concluded that the principal did not wish to participate in the study.

School Demographic Data

Data will be collected about the schools and school district participating in the study. This data will offer a description of the population being served by the school district and in each school. The data will also provide information regarding the leadership of the school district. This information, along with results from the TBEST questionnaire and ACT Science, will provide an in depth analysis of science instruction and possible methods of improvement for the schools and school district.

Procedure

The initial IRB correspondence and approval process began in spring 2016. This process entailed corresponding with the school district and with school principals to obtain approval. Multiple attempts to invite schools to participate in the study were conducted through the end of July 2016. The start of data collection began after receiving approvals from the IRB and the school principals. ACT data were collected throughout summer 2016, and survey data collection took place in August 2016. The window to complete the survey was approximately two weeks in duration. Multiple attempts were made to recruit science teachers to participate. A drawing for seven $25 gift cards was advertised to increase response rates. Table 3 outlines the procedure and time frame for the research study.

Data Analysis

The purpose of the study was to answer four research questions. The analysis for each research question was addressed with TBEST questionnaire data and ACT Science student achievement data.

Research Question 1

Research Question 1 was "Do teacher beliefs about science instruction align with Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction as measured by the TBEST questionnaire?" Teachers' beliefs science instructional were measured using the TBEST questionnaire. The questionnaire provided measurements of teacher beliefs about Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction (Smith et al., 2014). Teacher instruction was scored as agreement or disagreement with the TBEST items. The average response for each item was computed using the scores provided for each item in the three TBEST categories.

Table 3

Time Frame for Study

Timeline	Procedure
Spring 2016	Correspondence with school district office, IRB submission, and approval process
June 2016	Initial correspondence with district principals
June 2016	Second attempt of correspondence with district principals
June 2016	Third attempt of correspondence with district principals
July 2016	Fourth and final attempt of correspondence with district principals
June – July 2016	Start of data collect (student ACT raw scores and demographics)
July 2016	Initial data analysis of ACT data
August 2016	Initial correspondence and invitation to district science teachers to participate in survey
August 2016	Second attempt of correspondence to district science teachers to participate in survey
August 2016	Third attempt of correspondence to district science teachers to participate in survey
August 2016	Final attempt of correspondence to district science teachers to participate in survey
August 2016	Initial analysis of survey data on an individual and group level
August 2016	Final analysis of ACT and survey data

The level of agreement with each item and category of items was considered. Authors of the TBEST manual suggested two different labels for the responses of participants: high (agree) or low (disagree). In this study, the researcher recognized the variation in the scales used for the TBEST and accounted for it by differentiating between levels of agreement and disagreement. Teachers who scored high in multiple categories were placed in multiple classifications.

Research Question 2

Research Question 2 was "Do science teachers in a science department hold the same beliefs about science instruction?" The second research question was addressed through descriptive statistics gathered from the TBEST responses. In particular, the variance between responses of participants at each school and the variance for the overall population were examined. The coding and analysis completed for Research Question 1 were also considered when answering the second research question.

Teachers in the same science department, under similar leadership, participating in similar professional development, and continually interacting with one another were hypothesized to have similar instructional beliefs. The sphere of influence among teachers was expected to be reflected in the beliefs data. Each item on the TBEST questionnaire was tested for variance among participating teachers in the study. The variances that existed between participants from each school on the TBEST items was expected to be lower than the overall variance for the entire population in the study.

The analysis of Research Question 2 was limited to descriptive statistics because of the nature of the data collected. No particular treatments were assessed and the responses from each participant was considered. As a result, no comparable groups existed that would allow for more depth in the analysis.

Research Question 3

Research Question 3 was “Do science teachers at different schools in one school district hold the same beliefs about science instruction?” Similar to the findings for teachers in science departments within each school, teachers of the same school district would be expected to have consistent instructional belief. The third research question was addressed using an ANOVA followed by a Bonferroni post hoc analysis with individual items and item categories from the TBEST questionnaire. The ANOVA compared the science instructional beliefs of science departments in each school with one another. It was hypothesized that teachers in the same school district would hold similar instructional beliefs about science because of the common leadership, policies, and school district initiatives and implementations among the schools.

Addressing Research Question 3 with the statistical analysis of ANOVAs required having set groups of teachers within a single school district. The ANOVA itself is a statistical test that assesses the fit of a regression model (Field, 2013). For the ANOVA used to address Research Question 3, a ratio was produced that compared the systematic to unsystematic variances that existed between average responses on TBEST items of different science departments. This ratio, called the F ratio, provided evidence of differences that existed between the science departments based on size. A large F ratio indicated the ability to differentiate between the average responses of each science department (Field, 2013). Because the *F* ratio only indicated if a significant difference exists, further analysis was carried out with a post hoc test.

In this study, a Bonferroni post hoc test was used to compare the average responses between each school's science department. If the ANOVA proved to be significant, the results of the Bonferroni post hoc addressed the specific differences between science departments' responses on TBEST items that produced the significant *F* ratio.

The first ANOVA tested the independent variable *school science departments* against the dependent variable *average responses to TBEST items*. The second ANOVA tested the independent variable of school science departments against the dependent variable of average responses to TBEST categories of Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction.

Research Question 4

Research Question 4 was "What relationships exist between science departments with higher belief scores on TBEST Learning Theory and ACT Science achievement?" The fourth research question addressed how teacher beliefs aligned with student achievement. Specifically, this analysis showed how the average instructional beliefs of science departments correlated with student achievement on the ACT Science assessment. Science departments that held beliefs in agreement with Learning Theory science instruction on the TBEST were hypothesized to produce higher achieving students. The average response of each school's science department was tested for correlation with ACT Science achievement. The average variance among teachers at each school was also tested for correlation with ACT Science achievement.

Analysis of Research Question 4 started with Pearson correlation tests. These tests compared the variables of ACT Science achievement with both mean responses to TBEST categories and variance within responses. The Pearson correlation tests provided an analysis that could potentially show a positive correlation, a negative correlation, or no correlation at all (Field, 2013).

Other considerations were made while answering Research Question 4. Demographical data of each participating school and the overall school district were collected as possible variables contributing to ACT Science achievement. The history of the school district and its leadership were included in the data analysis for this research question. Considering the demographics of both the schools and school district facilitated an analysis with more depth, complementing the statistical analysis that was conducted.

Beyond analysis conducted comparing ACT Science achievement with various aspects of school science departments, ACT Science achievement data were analyzed alone. To provide a view of how individual schools and the school district progressed with ACT Science achievement, two ANOVAs were conducted. The ANOVAs tested the independent variables of graduating cohorts within schools and the overall population of the study against the dependent variable of ACT Science achievement. This analysis provided evidence that ACT Science performance could potentially be improving, digressing, or stagnant.

Table 4

Research Questions and Analysis Methods

Research Question	Mode of Analysis	Hypothesis
1. Do teacher beliefs about science instruction align with Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction as measured by the TBEST questionnaire?	Classify participants in the following based on average TBEST responses: Learning Theory, Confirmatory science, and/or hands-on all the time instruction	
2. Do science teachers in a science department hold the same beliefs about science instruction?	Descriptive statistics: mean response, variance; Coding from Research Question 1	
3. Do science teachers at different schools in one school district hold the same beliefs about science instruction?	ANOVA Bonferroni post hoc Independent variable: schools; Dependent variables: responses to TBEST items and categories	Hypothesis: Science teachers within the same school district will have the same beliefs about science instruction. Null hypothesis: Science teachers within the same school district do not hold the same beliefs about science instruction.
4. What relationships exist between science departments with higher belief scores compared to Learning Theory and ACT Science scores?	Correlational test: Dependent variable: ACT Science scores; independent variables: mean TBEST responses and variance	Hypothesis: Science departments with higher belief scores aligned with Learning Theory will have higher student achievement on ACT science. Null hypothesis: There is no difference between student performance within schools that have teachers with strong beliefs aligned with Learning Theory versus schools that have teachers with beliefs not emphasizing Learning Theory.

Limitations

Several limitations and constraints may have affected the validity of outcomes from this research. These concerns involve the TBEST instrument, the sample size of teachers, and the measurement of student achievement.

The original purpose of the TBEST questionnaire was to measure teacher beliefs as a dependent variable (Smith et al., 2014). This study, however, was not experimental in nature. Therefore, the absence of a treatment such as a professional development session meant that the study used the TBEST instrument purely as a measurement of teacher beliefs about science instruction. During development of the TBEST questionnaire, no form of treatment was used when validating the instrument (Smith et al., 2014). Therefore, the researcher concluded the TBEST questionnaire was a reasonable measurement of science instructional beliefs outside of an experimental setting.

Regarding sample size, science departments in the focus school district contained a limited number of possible participants. Approximately 15 teachers worked in each science department. Of these teachers, those new to the department for the 2016–2017 school year were not considered for the study because of their lack of influence on student ACT scores. Ideally, the survey data would have been collected at the end of the 2015–2016 school year, but because of time constraints, the window to participate in the survey occurred at the beginning of the 2016–2017 school year.

The ACT Science test was employed to measure student achievement for this study. The focus district required that students take the ACT during the spring semester of their 11^{th} grade year. Because the ACT Science test is not dependent on the content of any particular course, teachers of the entire science department were expected to have influence on student ACT achievement. The study, therefore, only associated students with their school science departments. Although this delimitation addressed the research questions, it may have limited the potential extent of analysis.

Summary

In this study, the researcher sought to provide a foundation for student achievement on the ACT Science assessment. The foundation consisted of an analysis of teacher beliefs about science instruction. These beliefs were measured using the TBEST questionnaire, which focused on three types of instruction: Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction (Smith et al., 2014).

Using the responses collected with the TBEST, an analysis was accomplished on the alignment of teacher beliefs with science Learning Theory (Smith et al., 2014). Further, the researcher also analyzed the alignment of beliefs throughout school science departments and the overall school district. Results from the TBEST questionnaire were used in conjunction with ACT Science achievement scores for an analysis of correlation. Chapter IV presents the results from the data collection and analysis procedures outlined in Chapter III.

CHAPTER IV

RESULTS

Introduction

This chapter is organized by the data collected and analysis completed. The chapter begins with demographical data of the schools and school district, followed by the data and analysis of the TBEST questionnaire and the ACT Science results. The chapter concludes with a summary of the results and analysis.

The data collected in the study came from four schools in one school district. The participants from each school were delimited to teachers in the science departments. The TBEST results and analyses were categorized into (a) individual responses from participants, (b) the average responses from each school, and (c) average responses of the participating schools within the school district. The demographical data from each school and the overall school district included (a) the overall enrollment of students, (b) annual budget, (c) leadership, (d) ethnicity breakdown by school, and (e) annual enrollment within the individual schools. The ACT Science results and analysis involved several different aspects. The first aspect presented is an overall analysis of the results, including consideration of the differences between schools, genders, and graduating cohorts. The second aspect is an analysis of the ACT Science results and responses on the TBEST questionnaire.

Demographic Data

Demographic data were collected for each participating school and for the school district from two different published sources. The first source was the state board of education report card. The governing state board of education for the school district publishes report cards for all public schools. Demographic data were pulled for each participating school for the 2012–2013, 2013–2014, and 2014–2015 school years. The data collected included student enrollment, economically disadvantage (ED) percentages, student ethnicity percentages, and the number of English language learners (ELL) at each school.

The second source was the school district's annual reports. Demographic data for the school district were collected from annual reports published by the school district. The data collected included annual student enrollment, annual budgeted funds, annual student expenditures, and annual teacher employment numbers. The data also included descriptive data about previous school district directors and the present and past members of the school district's board of education.

At the time of this study, the position of director of schools had been occupied by the same individual since the 2012 school year. Prior to taking the director position, this individual served as the curricula and instruction superintendent for the school district. Throughout this time, the members of the board of education experienced little change: Four of the members had served on the board throughout the term of the current director.

The school district's population and budget increased since the 2001–2002 school year (Table 5). The school district coexisted with a kindergarten through sixth grade (K–

6) school district. The consistent growth of the school district participating in this study is shown for each year except for the 2014–2015 school year. The K–6 school system opened a new school during this year, accounting for the dip in the rate of growth.

Table 5

School District Student Enrollment

School Year	School District Enrollment	Enrollment Increases
2001–2002	27,000	4.20%
2002–2003	28,200	4.40%
2003–2004	29,600	5.09%
2004–2005	31,300	5.58%
2005–2006	33,000	5.50%
2006–2007	34,800	5.65%
2007–2008	35,900	3.08%
2008–2009	36,700	2.29%
2009–2010	37,500	2.11%
2010–2011	38,400	2.27%
2011–2012	38,900	1.35%
2012–2013	39,900	2.60%
2013–2014	41,000	2.86%
2014–2015	41,400	0.87%
2015–2016	42,600	2.98%

Note. Student enrollment numbers rounded to maintain anonymity of the school district and participating schools.

In addition, the annual budget for the school district grew consistently since the 2001–2002 school year (Table 6). The amount budgeted for student expenditures, however, did not show the same rate of growth during the same time.

Table 6

School District Annual Budget

School Year	Annual Budget	Percentage Increase	Student Expenditures	Percentage Increase
2001–2002	$134,000,000	5.63%	$6,570	0.61%
2002–2003	$140,000,000	4.26%	$6,660	1.34%
2003–2004	$153,000,000	8.81%	$6,750	1.35%
2004–2005	$168,000,000	10.12%	$6,820	0.94%
2005–2006	$185,000,000	10.16%	$6,930	1.67%
2006–2007	$205,000,000	10.61%	$6,940	0.16%
2007–2008	$224,000,000	9.33%	$7,170	3.13%
2008–2009	$236,000,000	5.43%	$7,020	−2.15%
2009–2010	$243,000,000	2.93%	$7,170	2.20%
2010–2011	$257,000,000	5.78%	$7,350	2.45%
2011–2012	$267,000,000	3.93%	$7,260	−1.25%
2012–2013	$280,000,000	4.78%	$7,290	0.44%
2013–2014	$300,000,000	7.27%	$7,470	2.33%
2014–2015	$307,000,000	2.23%	$7,400	−0.91%
2015–2016	$323,000,000	5.37%	$7,650	3.27%

Note. Budget and student expenditure numbers rounded to maintain anonymity of the school district and participating schools.

The number of teachers employed by the school system was relative consistent from 2012 through 2015–2016. School 4 began operating for the 2013–2014 school year and accounted for the change in number of schools within the school district (Table 7).

Table 7

School District Employment

School Year	Teachers Employed	Total Employees	Number of Schools
2012–2013	2,880	4,690	45
2013–2014	3,100	5,050	46
2014–2015	2,950	4,910	46
2015–2016	3,020	4,990	46

Note. Values rounded to maintain anonymity of school district.

Each of the schools served a relatively similar population of students (Table 8). Since the 2012–2013 school year, School 1 served a student population of over 1,800 students. Approximately 40% of the students were economically disadvantaged. The majority of the students were White, followed by Blacks, Hispanics, and Asians.

School 2 showed a population over 1,800 students since the 2012–2013 school year. Approximately 30% of the students were economically disadvantaged. School 2 had an ethnical makeup similar to the makeup of School 1, with a higher percentage of Asian students, compared to Hispanic students.

Table 8

School-Level Demographics

	School Year	White %	Black %	Asian %	Hisp. %	Native Amer. %	ED %	ELL %	Total
School 1	2012–2013	63.2	26.5	3.8	6.2	0.2	42.0	3.5	1,860
	2013–2014	61.0	25.9	3.7	9.0	0.5	43.0	2.7	1,930
	2014–2015	59.1	26.5	4.1	10.0	0.3	39.0	2.7	1,980
School 2	2012–2013	71.4	18.6	5.8	4.1	0.1	32.0	1.4	2,020
	2013–2014	72.5	16.2	5.8	5.2	0.3	31.0	1.2	1,890
	2014–2015	72.1	16.2	6.3	5.0	0.4	30.0	0.7	1,860
School 3	2012–2013	65.4	16.3	6.2	12.1	0.0	45.0	4.4	1,990
	2013–2014	62.5	16.9	6.2	14.2	0.2	50.0	4.6	1,810
	2014–2015	59.7	18.0	6.1	16.1	0.1	47.0	5.8	1,770
School 4	2012–2013								
	2013–2014	70.4	17.9	4.5	7.0	0.1	34.0	1.6	1,380
	2014–2015	70.6	17.6	4.0	7.7	0.1	28.0	1.3	1,700

Note. White, Black, Asian, Hispanic, Native American, economically disadvantaged (ED), and English language learners (ELL) values are all reported in percentages. Reported percentages and total student enrollment values are rounded to maintain anonymity of school district and schools. School 4 was not open during the 2012–2013 school year.

School 3 served a student population of over 1,800 for the 2012–2013 and 2013–2014 school years; however, the population dipped below 1,800 for the 2014–2015 school year. School 3 served a majority of White students, followed by Black, Hispanic, and Asian students. School 4 opened with just under 1,400 students in the 2013–2014 school year. The 2014–2015 population spiked to just over 1,700 students. The majority of these students were White, followed by Black, Hispanic, and Asian. Approximately 30% of School 4 students were classified as economically disadvantaged.

TBEST Questionnaire Results

Participant Response Scores

The Teacher Beliefs about Effective Science Teaching (TBEST) questionnaire contains items classified into instructional categories aligned with Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction (Smith et al., 2014). The TBEST questionnaire required respondents to agree or disagree with each statement on a 6-point scale, allowing for variances in the degree of agreement or disagreement. Smith, Smith, and Banilower (2014) suggested classifying results as either *high* or *low*, indicating the extent to which the participant agreed (high) or disagreed (low) with an item. To differentiate individual responses in this study, the degree of agreement and disagreement, the descriptors of *slightly high* and *slightly low* were used in addition to *high* and *low* when describing the responses of participants. The descriptor *slightly high* referred to average scores between 4.0 to 4.9. *Slightly low* indicated an average score between 3.0 to 3.9. Scores greater than 5.0 and below 3.0 were categorized as *high* and *low*. Each school's science department average scores are displayed in Table 9, Table 10, Table 11, and Table 12.

Table 9

School 1 TBEST Composite Scores and Descriptors of Participants (N = 11)

Composite Scores			Composite Descriptors		
Learning Theory	Confirmatory	Hands-on	Learning Theory	Confirmatory	Hands-on
5.2	5.1	4.3	High	High	Slightly high
5.6	3.4	3.3	High	Slightly low	Slightly low
5.9	3.3	3.0	High	Slightly low	Slightly low
5.8	4.7	4.0	High	Slightly high	Slightly low
5.9	3.0	2.0	High	Slightly low	Low
5.4	2.3	1.0	High	Low	Low
5.4	4.7	4.0	High	Slightly high	Slightly low
4.8	3.0	2.7	Slightly high	Slightly low	Low
5.6	3.7	1.7	High	Slightly low	Low
5.5	3.4	2.0	High	Slightly low	Low
5.7	3.6	4.3	High	Slightly low	Slightly high

Note. The concepts of Learning Theory, Confirmatory instruction, and All Hands-on All the Time science instruction are concepts used within the TBEST questionnaire (Smith et al., 2014). *Learning Theory* refers to the latest research on science instruction. *Confirmatory* refers to instructional activities used to confirm content taught to students. *All Hands-on All the Time (hands-on)* refers to instructional hands-on activities taking precedence over learning content.

School 1 participants scored above a mean of 4 on the 6-point scale on learning-theory items, indicating agreement with these items. Further, only a single participant scored an average below a 5 on Learning Theory science instruction items indicating consistently strong agreement with the items. Scores on Confirmatory science instruction and All Hands-on All the Time science instruction items were associated with a mixture of agreement and disagreement responses by participants. The mean responses within School 1 overall show higher agreement on Learning Theory items in comparison to Confirmatory and All Hands-on All the Time items.

Table 10

School 2 TBEST Composite Scores and Descriptors (N = 11)

Composite Scores			Composite Descriptors		
Learning Theory	Confirmatory	Hands-on	Learning Theory	Confirmatory	Hands-on
4.6	3.3	4.3	Slightly high	Slightly low	Slightly high
5.1	4.0	1.7	High	Slightly low	Low
4.7	4.6	4.3	Slightly high	Slightly high	Slightly high
5.6	2.9	1.7	High	Low	Low
5.0	4.0	2.0	Slightly high	Slightly low	Low
5.6	3.9	1.0	High	Slightly low	Low
5.4	2.7	4.0	High	Low	Slightly low
5.2	2.3	4.0	High	Low	Slightly low
4.8	2.7	4.3	Slightly high	Low	Slightly high
5.7	4.6	3.3	High	Slightly high	Slightly low
5.3	3.6	2.0	High	Slightly low	Low

Note. The concepts of Learning Theory, Confirmatory instruction, and All Hands-on All the Time science instruction are concepts used within the TBEST questionnaire (Smith et al., 2014). *Learning Theory* refers to the latest research on science instruction. *Confirmatory* refers to instructional activities used to confirm content taught to students. *All Hands-on All the Time (hands-on)* refers to instructional hands-on activities taking precedence over learning content.

Five of the 11 School 2 participants scored average agreement above 5 on Learning Theory science instruction items. School 2 showed three participants with average agreement scores above 3 on the categories of Confirmatory science instruction and All Hands-on All the Time science instruction items.

Table 11

School 3 TBEST Composite Scores and Descriptors (N = 11)

Composite Scores			Composite Descriptors		
Learning Theory	Confirmatory	Hands-on	Learning Theory	Confirmatory	Hands-on
4.4	4.4	2.0	Slightly high	Slightly high	Low
5.5	3.6	2.0	High	Slightly low	Low
5.4	3.1	2.7	High	Slightly low	Low
5.8	4.4	4.3	High	Slightly high	Slightly high
5.1	4.0	3.3	High	Slightly low	Slightly low
5.0	4.7	4.0	Slightly high	Slightly high	Slightly low
4.9	4.4	3.3	Slightly high	Slightly high	Slightly low
5.7	3.9	4.0	High	Slightly low	Slightly low
5.6	4.9	3.7	High	Slightly high	Slightly low
5.5	3.7	3.3	High	Slightly low	Slightly low
5.7	3.0	1.0	High	Slightly low	Low

Note. The concepts of Learning Theory, Confirmatory instruction, and All Hands-on All the Time science instruction are concepts used within the TBEST questionnaire (Smith et al., 2014). *Learning Theory* refers to the latest research on science instruction. *Confirmatory* refers to instructional activities used to confirm content taught to students. *All Hands-on All the Time (hands-on)* refers to instructional hands-on activities taking precedence over learning content.

Eight of the 11 School 3 participants scored above a mean of 5 on learning-theory items. With five participants and a mean score of 4.6, School 3 had the most participants responding in agreement on average with Confirmatory items.

Table 12

School 4 TBEST Composite Scores and Descriptors (N = 8)

Composite Scores			Composite Descriptors		
Learning Theory	Confirmatory	Hands-on	Learning Theory	Confirmatory	Hands-on
5.3	2.7	2.0	High	Low	Low
5.6	2.7	3.7	High	Low	Slightly low
5.5	3.9	3.0	High	Slightly low	Slightly low
5.6	2.7	1.0	High	Low	Low
5.4	4.0	2.0	High	Slightly low	Low
5.7	3.9	3.3	High	Slightly low	Slightly low
5.7	3.9	4.0	High	Slightly low	Slightly low
5.5	4.1	4.3	High	Slightly high	Slightly high

Note. The concepts of Learning Theory, Confirmatory instruction, and All Hands-on All the Time science instruction are concepts used within the TBEST questionnaire (Smith et al., 2014). *Learning Theory* refers to the latest research on science instruction. *Confirmatory* refers to instructional activities used to confirm content taught to students. *All Hands-on All the Time (hands-on)* refers to instructional hands-on activities taking precedence over learning content.

All eight School 4 participants scored average agreement above 5 on the Learning Theory science instruction items. School 4 showed the least number of participants; only one person agreed on Confirmatory science instruction and All Hands-on All the Time science instruction items.

Classification of Individual Participants

The responses to each item were averaged to determine an overall score within each instructional category. A profile was developed for each participant depending on high responses (agreement) or low responses (disagreement) to items in each instructional category (see Table 13 and Figure 5). Participants were classified into the following belief profiles, reflecting their averaged high responses to the TBEST questionnaire items:

1. Only Learning Theory science instruction
2. Both Learning Theory science instruction and Confirmatory science instruction
3. Both Learning Theory science instruction and All Hands-on All the Time science instruction
4. Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction (all three)

Participants in the classification *Learning Theory science instruction* scored high only on items pertaining to Learning Theory science instruction and low on items in the categories of Confirmatory science instruction and All Hands-on All the Time science instruction. Those participants in the *Learning Theory science instruction and Confirmatory science instruction* profiles only scored low on All Hands-on All the Time science instruction items only. Participants who scored low only on Confirmatory science instruction items received the profile of *Learning Theory science instruction and All Hands-on All the Time science instruction*. Finally, participants who scored high on all three item categories were given the beliefs profile of alignment to all three categories.

Table 13

Number of Participants in Agreement With TBEST Item Categories (N = 41)

	Learning Theory	Learning Theory & Confirmatory	Learning Theory & Hands-on	All three
School 1 (*N* = 11)	7	2	1	1
School 2 (*N* = 11)	7	1	2	1
School 3 (*N* = 11)	6	4	0	1
School 4 (*N* = 8)	7	0	0	1

Note. The concepts of Learning Theory, Confirmatory instruction, and All Hands-on All the Time science instruction are concepts used within the TBEST questionnaire (Smith et al., 2014). *Learning Theory* refers to the latest research on science instruction. *Confirmatory* refers to instructional activities used to confirm content taught to students. *All Hands-on All the Time (hands-on)* refers to instructional hands-on activities taking precedence over learning content.

Smith et al. (2014) describe the ideal responses on the TBEST questionnaire as responding in agreement with Learning Theory items but disagreement with both Confirmatory and All Hands-on All the Time items. On the TBEST response scale, this would be reflected with High responses on Learning Theory items, and Low responses on both Confirmatory, and All Hands-on All the Time items. Those participants categorized as *Learning Theory* in Table 13 fit the description of Smith et al.

School 1 participants' responses reflected all four belief profiles. The majority of participants (7 of 11) scored high only on Learning Theory science instruction. Two scored high only on Learning Theory science instruction and Confirmatory science instruction items. One of the participants from School 1 scored high on both Learning Theory science instruction and All Hands-on All the Time science instruction items. Finally, one participant scored high on all three categories.

School 2 showed results similar to those of School 1. Seven of the 11 participants at School 2 scored high only on items pertaining to Learning Theory science instruction. Two were classified as scoring in agreement with Learning Theory and All Hands-on All the Time items. One participant scored high on both Learning Theory and Confirmatory science instruction, and one participant scored high on all three categories.

Compared to Schools 1 and 2, a higher number of School 3 participants scored high on Confirmatory science instruction. Six of the 11 School 3 participant scored high on Learning Theory instruction items only; four scored high on Learning Theory science instruction and Confirmatory science instruction. A single participant scored high on all three categories.

Seven of 8 School 4 participants scored high on Learning Theory science instruction items alone. One participant scored high on all three categories. The main difference between School 4 and the three other school was the number of participants. Schools 1, 2, and 3 each had 11 participants, and School 4 had only eight.

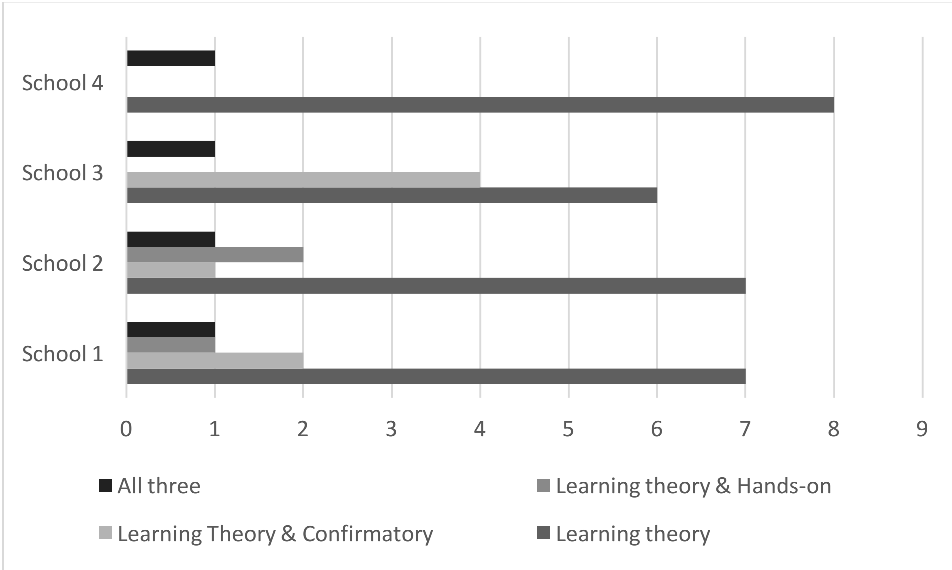

Figure 5. Belief profiles for each participating school ($N = 41$).

Note. The concepts of Learning Theory, Confirmatory instruction, and All Hands-on All the Time science instruction are concepts used within the TBEST questionnaire (Smith et al., 2014). *Learning Theory* refers to the latest research on science instruction. *Confirmatory* refers to instructional activities used to confirm content taught to students. *All Hands-on All the Time (hands-on)* refers to instructional hands-on activities taking precedence over learning content.

School Science Department Response Scores

The composite means of all four schools (Table 14) indicated that each science department on average agreed with items related to Learning Theory science instruction. Each school except School 3 averaged low or slightly low scores on items relating to Confirmatory science instruction and All Hands-on All the Time science instruction. School 3 was the only school in the study to have response scores that averaged in the slightly high range for Confirmatory science instruction.

Table 14

School TBEST Composite Scores and Descriptors (N = 41)

	Composite Scores			Composite Descriptors		
School	Learning Theory	Confirmatory	Hands-on	Learning Theory	Confirmatory	Hands-on
Overall	5.4	3.7	3.0	High	Slightly low	Slightly low
1	5.5	3.7	2.9	High	Slightly low	Low
2	5.2	3.5	3.0	High	Slightly low	Slightly low
3	5.3	4.0	3.1	High	Slightly high	Slightly low
4	5.5	3.5	2.9	High	Slightly low	Low

Note. The concepts of Learning Theory, Confirmatory instruction, and All Hands-on All the Time science instruction are concepts used within the TBEST questionnaire (Smith et al., 2014). *Learning Theory* refers to the latest research on science instruction. *Confirmatory* refers to instructional activities used to confirm content taught to students. *All Hands-on All the Time (hands-on)* refers to instructional hands-on activities taking precedence over learning content.

An overall difference in the degree of responses was evident in the composite scores for each school. School 4 demonstrated the greatest difference between categories, showing high agreement on Learning Theory science instruction items and disagreement to a greater degree on Confirmatory science instruction and All Hands-on All the Time science instruction items, compared to the other schools. Further analysis regarding the differences in responses from each school on the TBEST questionnaire is available (see APPENDIX B: AVERAGE SCHOOL RESPONSES TO TBEST ITEMS).

Item 7 on TBEST questionnaire was the most agreed-upon item. This item pertained to Learning Theory science instruction and stated, “Teachers should ask students to support their conclusions about a science concept with evidence” (Smith et al., 2014). Each participant in School 1 and School 4 responded with the highest degree of agreement (*M* = 6, *SD* = 0.000). Item 2 on the other hand displayed the most diversity in responses (*M* = 4.37, *SD* = 1.43). Item 2 was a Confirmatory science instruction item: "Hands-on activities and/or laboratory activities should be used primarily to reinforce a science concept that the students have already learned" (Smith et al., 2014). School 2 accounted for the widest range of responses for the item (*M* = 4.27, *SD* = 1.68).

Ultimately, Learning Theory science instruction items showed the most consistent responses among each of the schools (Table 15). The average Learning Theory item response indicated agreement. Upon further analysis, for each individual Learning Theory item, all schools in the study averaged an agreement response. The lowest-rated Learning Theory science instruction item was Item 15. This item stated, "Students' ideas about a science concept should be deliberately brought to the surface prior to a lesson or unit so that students are aware of their own thinking" (Smith et al., 2014).

Table 15

Science Department Average Response to TBEST Item Categories (N = 41)

		Mean	Standard Deviation *(SD)*	Variance
School 1	Learning Theory	5.53	0.65	0.42
	Confirmatory	3.66	1.44	2.07
	Hands-on	2.94	1.32	1.75
School 2	Learning Theory	5.19	0.73	0.54
	Confirmatory	3.49	1.60	2.57
	Hands-on	2.97	1.43	2.03
School 3	Learning Theory	5.33	0.90	0.81
	Confirmatory	4.01	1.65	2.72
	Hands-on	3.06	1.25	1.56
School 4	Learning Theory	5.55	0.59	0.34
	Confirmatory	3.48	1.57	2.47
	Hands-on	2.92	1.59	2.51
Overall	Learning Theory	5.39	0.75	0.56
	Confirmatory	3.68	1.57	2.48
	Hands-on	2.98	1.37	1.88

Note. The concepts of Learning Theory, Confirmatory instruction, and All Hands-on All the Time science instruction are concepts used within the TBEST questionnaire (Smith et al., 2014). *Learning Theory* refers to the latest research on science instruction. *Confirmatory* refers to instructional activities used to confirm content taught to students. *All Hands-on All the Time (hands-on)* refers to instructional hands-on activities taking precedence over learning content.

Variance within School Science Department Responses

The overall variance of Learning Theory science instruction for School 1 was lowest of the three categories (M = 5.53, SD = 0.65). This held true for each of the participating schools, as shown in Table 15 and Figure 6. (See APPENDIX C: SCHOOL VARIANCES ON TBEST ITEMS for a complete list.) The items with the least variance for School 1 included Item 7 and Item 6. Both items are categorized as Learning Theory science instruction. For Item 7, all participants at School 1 responded identically.

School 2 participant responses showed smaller variances on TBEST Item 3 (M = 3.45, SD = 0.54), Item 6 (M = 5.45, SD = 0.52), and Item 17 (M = 5.64, SD = 0.51) compared to the variance found for Item 7 (M = 5.37, SD = 0.67). These findings contrasted with the variances for School 1 and School 4, where no variances existed for Item 7 because each participant in each school responded identically (M = 6.00, SD = 0.00). School 2 (M = 3.49, SD = 1.60) and School 3 (M = 4.01, SD = 1.65) responses showed the most variance among Confirmatory items in comparison with School 1 and School 4.

School 3 responses showed the lowest variance on Item 7 (M = 5.82, SD = 0.41) and highest variance on Item 13 (M = 2.91, SD = 1.38). Item 13 aligned with the All Hands-on All the Time science instruction TBEST category. The item stated: "Teachers should have students do interesting hands-on activities, even if the activities do not relate closely to the concept being studied" (Smith et al., 2014). The item contrasted with Learning Theory science instruction items, which were consistent with the average disagreement score for the statement. However, the large variance indicated a wider range of responses to this item among School 3 participants.

School 4 responses showed the lowest variance among items associated with Learning Theory science instruction (M = 5.55, SD = 0.59). The variance for

Confirmatory items (*M* = 3.49, *SD* = 1.60) and All Hands-on All the Time items (*M* = 2.92, *SD* = 1.59) was over seven times larger than it was for Learning Theory items. School 4 showed the lowest variance on Item 7 (*M* = 6.00, *SD* = 0.00) and highest variance on Item 19 (*M* = 3.63, *SD* = 1.92). Item 19 was categorized as a Confirmatory science instruction item. The results for Items 7 and 19 support the variance found between item categories for School 4. School 4 demonstrated the lowest variance on Learning Theory science instruction items (*M* = 5.55, *SD* = 0.59) but the highest on items pertaining to Confirmatory science instruction items (*M* = 3.48, *SD* = 1.57).

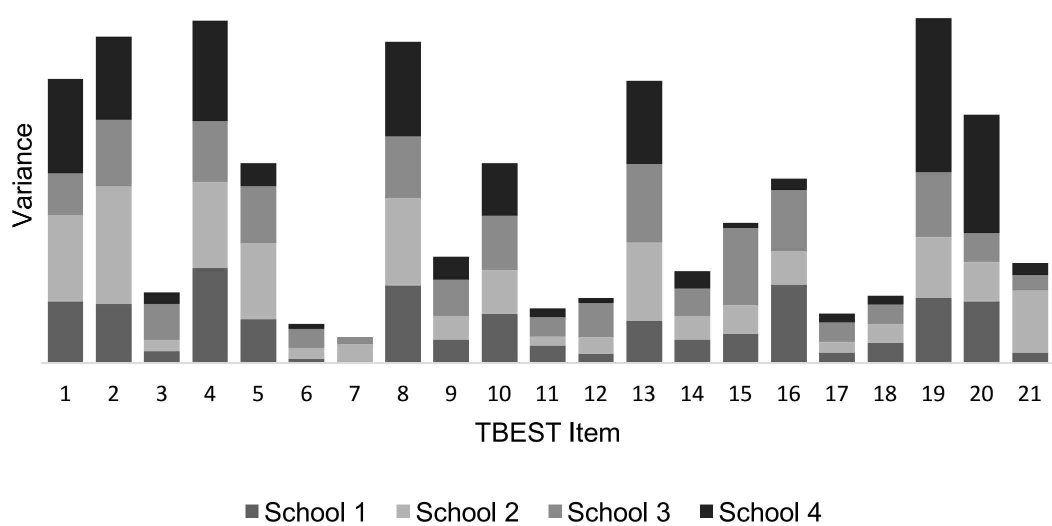

Figure 6. Variances of responses on TBEST items (*N* = 41).
The amount of variance for each school is reflected by total area charted. School 4 (yellow) averaged the lowest variance on Learning Theory items.

The lowest levels of variance are represented by the smallest peaks (Items 3, 6, 7, 9. 11, 12, 14, 15, 17, 18, 21). These items were all categorized as items associated with Learning Theory science instruction. Within those items, School 4 (yellow) displayed the least amount of variance among schools. In contrast, School 4 displayed the most variance on items categorized as both Confirmatory science instruction and All Hands-on All the Time science instruction.

TBEST Learning Theory School Results

The TBEST questionnaire consisted of specific items associated with Learning Theory science instruction (Items 3, 6, 7, 9. 11, 12, 14, 15, 17, 18, and 21). These items were designed based upon the most recent literature related to science instruction (Smith et al., 2014). A comparison between participating schools and the overall population responses is presented in Table 16 and Figure 7.

Except for Item 11 and Item 18, School 1 demonstrated lower variance compared to the overall population variance in the study for each of the other Learning Theory science instruction items. Item 11 states "Teachers should provide students with opportunities to apply the concepts they have learned in new or different contexts" (Smith et al., 2014, p. 9). The item had a population variance of 0.349 (M = 5.59, SD = 0.591) (See APPENDIX C: SCHOOL VARIANCES ON TBEST ITEMS for a complete list). School 1 had a variance of 0.418 (M = 5.73, SD = 0.647). Item 18 states: "Students should consider evidence that relates to the science concept they are studying" (Smith et al., 2014, p. 9). The population variance for Item 18 was 0.406 (M = 5.49, SD = 0.637), and for School 1, the variance was 0.473 (M = 5.45, SD = 0.688). Both School 2 and

School 3 showed variances larger than the population variance for Item 18. However, both School 2 and School 3 had lower variances than the population variance on Item 11.

Table 16

Learning Theory Science Item Mean and Variance

	Overall		School 1		School 2		School 3		School 4	
Item	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
3	5.34	.480	5.45	.273	4.91	0.291	5.64	0.855	5.38	.268
6	5.71	.262	5.91	.091	5.45	0.273	5.64	0.455	5.88	.125
7	5.78	.226	6.00	.000	5.36	0.455	5.82	0.164	6.00	.000
9	5.29	.612	5.18	.564	5.18	0.564	5.45	0.873	5.38	.554
11	5.59	.349	5.73	.418	5.27	0.218	5.64	0.455	5.75	.214
12	5.44	.502	5.73	.218	5.00	0.400	5.27	0.818	5.88	.125
14	4.88	.560	5.18	.564	4.82	0.564	4.64	0.655	4.88	.411
15	4.76	.889	4.91	.691	4.91	0.691	4.36	1.855	4.88	.125
17	5.66	.280	5.64	.255	5.64	0.255	5.64	0.455	5.75	.214
18	5.49	.406	5.45	.473	5.45	0.473	5.36	0.455	5.75	.214
21	5.34	.630	5.64	.255	5.09	1.49	5.18	0.364	5.50	.286

Note. For School 1, N = 11; School 2, N = 11; School 3, N = 11; School 4, N = 8. *Learning Theory* refers to the latest research on science instruction (Smith et al., 2014). See the items from the TBEST in APPENDIX A: TBEST QUESTIONNAIRE.

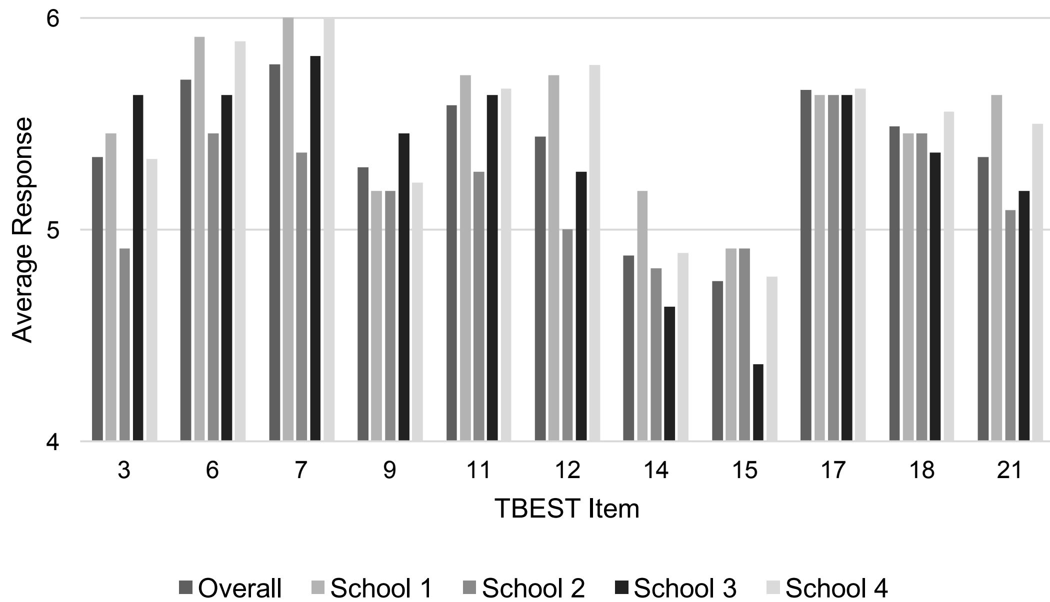

Figure 7. Comparison of responses on Learning Theory science instruction TBEST items (*N* = 41).

Each average reflected a response in agreement with the TBEST item. Maxium degree of agreement was 6.

School 2 and School 3 science teachers showed a larger variance among responses to TBEST items. School 2 had larger variance compared to the population variance on Item 6, Item 7, Item 14, and Item 18. School 3 displayed larger variances compared to the population on Item 6, Item 9, Item 12, Item 15, and Item 18. Item 6 was common between the two school. The item states “Teachers should provide students with opportunities to connect the science they learn in the classroom to what they experience outside of the classroom” (Smith et al., 2014). Overall, School 3 showed a mean variance greater for Learning Theory items in comparison to the population variance.

School 4’s science teachers showed lower variances on all Learning Theory science instruction items in comparison to the population variance. As a result, School 4 showed the lowest average variance on Learning Theory science instruction items. Although School 4 displays the highest number of aligned beliefs on Learning Theory items, Figure *7* shows that each schools’ averaged responses reflected agreement on Learning Theory science instruction items.

Item 14 and Item 15 displayed the lowest average agreement within schools. Item 14 stated, “At the beginning of lessons, teachers should ‘hook’ students with stories, video, clips, demonstrations or other concrete events/activities in order to focus student attention” (Smith et al., 2014). This item directly related to motivating students. Item 15 stated, “Students’ ideas about a science concept should be deliberately brought to the surface prior to a lesson or unit so that students are aware of their own thinking.” This item related to the practice of surfacing students’ prior knowledge. These responses are evidence that participants did not consistently score low on one aspect of Learning Theory science instruction.

TBEST Confirmatory School Results

The TBEST questionnaire presented specific items associated with Confirmatory science instruction (Items 1, 2, 5, 10, 16, 19, and 20). These items were designed to identify beliefs aligned with instructional methods associated with assigning activities to confirm what has already been taught (Smith et al., 2014). School data for these items are presented with responses from the overall population (Table 17 and Figure 8).

Table 17

Confirmatory Science Instruction TBEST Items

	Overall		School 1		School 2		School 3		School 4	
Item	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
1	4.63	1.588	4.55	1.473	4.55	2.073	5.00	1.000	4.38	2.268
2	4.37	2.038	3.73	1.418	4.27	2.818	5.00	1.600	4.50	2.000
5	3.85	1.528	3.36	1.055	3.73	1.818	4.82	1.364	3.38	0.554
10	4.66	1.230	4.82	1.164	4.45	1.073	5.09	1.291	4.13	1.268
16	2.24	1.139	2.45	1.873	2.00	0.800	2.45	1.473	2.00	0.286
19	3.83	1.845	4.18	1.564	3.64	1.455	3.82	1.564	3.63	3.696
20	2.15	1.378	2.55	1.473	1.82	0.964	1.91	0.691	2.38	2.839

Note. For School 1, N = 11; School 2, N = 11; School 3, N = 11; School 4, N = 8. *Confirmatory* refers to instructional activities used to confirm content taught to students. See the items from the TBEST in APPENDIX A: TBEST QUESTIONNAIRE.

The population variance for responses on Confirmatory science instruction items was generally greater than variances found for School 1 and School 3. School 1 had a greater variance than the population variance on Item 16 (M = 2.45, SD = 1.37) and Item 20 (M = 2.55, SD = 1.21). School 3 displayed lower variance on all but two Confirmatory science instruction items: Item 10 (M = 5.09, SD = 1.136) and Item 16 (M = 2.45, SD = 1.214).

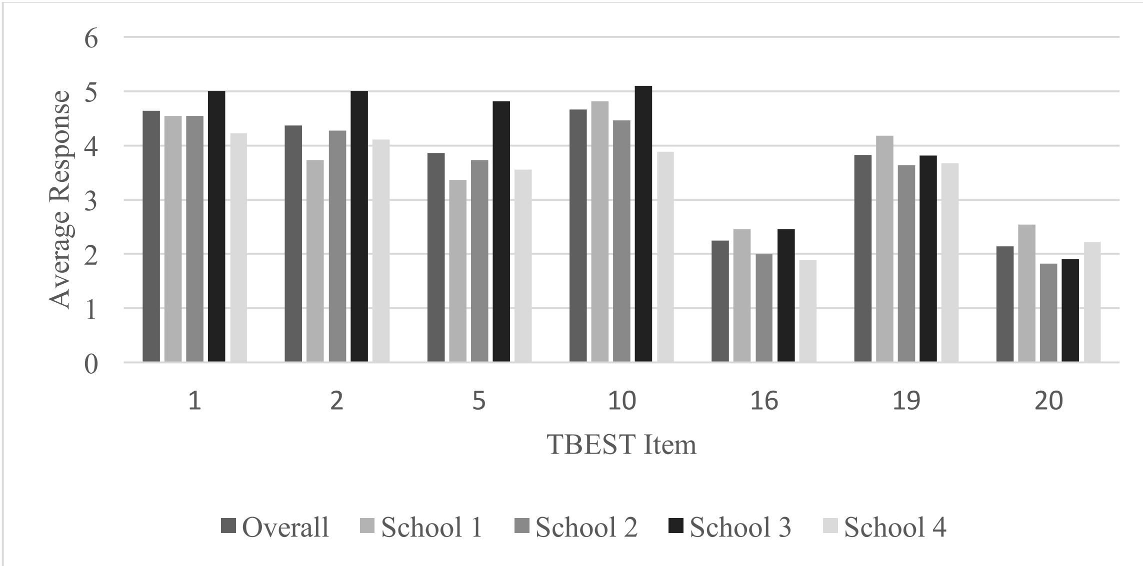

Figure 8. Comparison of responses on Confirmatory science instruction TBEST items ($N = 41$).

A mixture of agreement and disagreement responses was seen on Confirmatory science instruction items.

School 2 and School 4 showed greater variances compared to the population variance on more items, compared to School 1 and School 3. The items for School 2 included Item 1 ($M = 4.55$, $SD = 1.440$), Item 2 ($M = 4.27$, $SD = 1.679$), and Item 5 ($M = 3.73$, $SD = 1.348$). For School 4, the items included Item 1 ($M = 4.38$, $SD = 1.506$), Item 10 ($M = 4.13$, $SD = 1.126$), Item 19 ($M = 3.63$, $SD = 1.923$), and Item 20 ($M = 2.38$, $SD = 1.685$).

The average variance between responses on Confirmatory science instruction items proved to be larger than the average variance found on for Learning Theory science instruction items. This also held true when comparing the variances between responses for Confirmatory science instruction items and All Hands-on All the Time science instruction items.

The TBEST items associated with Confirmatory science instruction displayed a mixture of responses varying in agreement and disagreement. Item 16 and Item 20 displayed average responses in disagreement within the item, and Item 1 and Item 10 had average responses in agreement.

TBEST All Hands-on All the Time School Results

The TBEST questionnaire included specific items associated with All Hands-on All the Time science instruction (Item 4, Item 8, and Item 13). The items identified instruction in which students are given activities to complete whether or not those activities contribute to the desired content being taught (Smith et al., 2014). School response data are presented with response data from the overall population of the study (Table 18 and Figure 9).

Table 18

All Hands-on All the Time Science Instruction TBEST Items

	Overall		School 1		School 2		School 3		School 4	
Item	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
4	3.51	1.906	3.45	2.273	3.45	2.073	3.36	1.455	3.88	2.411
8	2.73	1.801	2.64	1.855	2.91	2.091	2.91	1.491	2.38	2.268
13	2.68	1.572	2.73	1.018	2.55	1.873	2.91	1.891	2.50	2.000

Note. For School 1, N = 11; School 2, N = 11; School 3, N = 11; School 4, N = 8. *All Hands-on All the Time (hands-on)* refers to instructional hands-on activities taking precedence over learning content. See the items from the TBEST in APPENDIX A: TBEST QUESTIONNAIRE.

All schools within the study had at least one All Hands-on All the Time science instruction item with greater variance than the population variance. Both School 2 and School 4 displayed greater variances than the population variance on all items associated with All Hands-on All the Time science instruction. School 1 showed greater variance on Item 2 (M = 2.64, SD = 1.362) compared to the population variance. School 3 displayed greater variance on item 13 (M = 2.91, SD = 1.375) compared to the population variance.

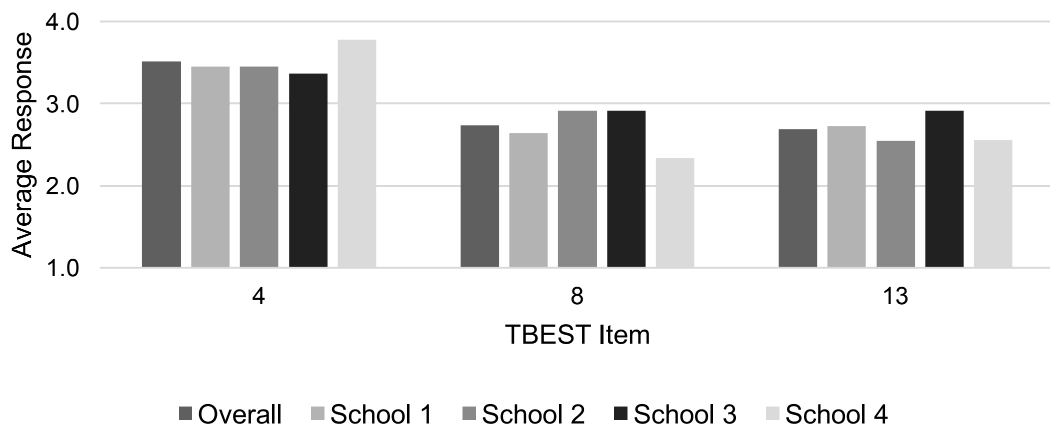

Figure 9. Comparison of responses on hands-on science instruction TBEST items (N = 41).
Average responses on All Hands-on All the Time science instruction items indicated disagreement.

Item 8 and Item 13 showed an average response that clearly reflected disagreement with the items. Item 4 had a mixture of responses reflecting agreement and disagreement. The item stated, “Teachers should have students do hands-on activities, even if the data they collect are not closely related to the concept they are studying” (Smith et al., 2014). This reflected completing hands-on activities for the purpose of just doing an activity. This is in contrast with doing an activity with an intended learning outcome.

School District Comparison of TBEST Items

The population used for this study consisted of teachers from four different schools from one school district. The school district scores were analyzed using an ANOVA (APPENDIX D: SCHOOL TBEST ANOVA RESULTS). The ANOVA used the four schools as an independent variable and TBEST item responses as the dependent variable. The ANOVA test identified statistically significant variance between and within the four different schools. The descriptive statistics took into account participant scores on individual items from the TBEST as well as categorical scores (i.e., Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction).

Overall, the four schools in the school district collectively showed similar results to responses from individual schools. Learning Theory science instruction items had an average response indicating agreement among the schools (M = 5.39, SD = 0.75). The responses to items that reflected Confirmatory science instruction and All Hands-on All the Time science instruction indicated disagreement by the population (Confirmatory: M = 3.68, SD = 1.57; All Hands-on All the Time: M = 2.98, SD = 1.37). The variance between responses increased among items dealing with Confirmatory science instruction and All Hands-on All the Time science instruction items (Table 19). When comparing responses between the participating schools of the school district, TBEST Item 5, $F(3, 37) = 4.961$, $p = .015$; Item 7, $F(3, 37) = 5.671$, $p = .003$; and Item 12, $F(3, 37) = 3.933$,

p = .016, indicated significant relationships between responses. All other items showed no significant difference between responses from each school.

Table 19

Bonferroni Multiple Comparisons of TBEST Items (N = 41)

Dependent Variable	School	School	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Lower	Upper
Item 5	School 1	2	−0.364	.477	1.000	−1.69	0.97
		3	−1.455*	.477	0.025	−2.78	−0.13
		4	−0.011	.519	1.000	−1.46	1.44
	School 2	1	0.364	.477	1.000	−0.97	1.69
		3	−1.091	.477	0.167	−2.42	0.24
		4	0.352	.519	1.000	−1.10	1.80
	School 3	1	1.455*	.477	0.025	0.13	2.78
		2	1.091	.477	0.167	−0.24	2.42
		4	1.443	.519	0.051	0.00	2.89
	School 4	1	0.011	.519	1.000	−1.44	1.46
		2	−0.352	.519	1.000	−1.80	1.10
		3	−1.443	.519	0.051	−2.89	0.00

Table 19 (continued)

Dependent Variable	School	School	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Lower	Upper
Item 7	School 1	2	.636*	.174	.005	0.15	1.12
		3	.182	.174	1.000	−0.30	0.67
		4	.000	.190	1.000	−0.53	0.53
	School 2	1	−.636*	.174	0.005	−1.12	−0.15
		3	−.455	.174	0.078	−0.94	0.03
		4	−.636*	.190	0.011	−1.17	−0.11
	School 3	1	−.182	.174	1.000	−0.67	0.30
		2	.455	.174	0.078	−0.03	0.94
		4	−.182	.190	1.000	−0.71	0.35
	School 4	1	.000	.190	1.000	−0.53	0.53
		2	.636*	.190	0.011	0.11	1.17
		3	.182	.190	1.000	−0.35	0.71
Item 12	School 1	2	.727	.274	0.069	−0.04	1.49
		3	.455	.274	0.631	−0.31	1.22
		4	−.148	.298	1.000	−0.98	0.68
	School 2	1	−.727	.274	0.069	−1.49	0.04
		3	−.273	.274	1.000	−1.04	0.49
		4	−.875*	.298	0.034	−1.71	−0.04
	School 3	1	−.455	.274	0.631	−1.22	0.31
		2	.273	.274	1.000	−0.49	1.04
		4	−.602	.298	0.304	−1.43	0.23
	School 4	1	.148	.298	1.000	−0.68	0.98
		2	.875*	.298	0.034	0.04	1.71
		3	.602	.298	0.304	−0.23	1.43

Note. *The mean difference was significant at the 0.05 level.

The Bonferroni post hoc test determined the schools that showed significant difference in response to Item 5, Item 7, and Item 12. For Item 5, School 1 (*M* = 3.36, *SD* = 1.027) showed a significant difference in responses compared to School 3 (*M* = 4.82, *SD* = 1.348). For Item 7, both School 1 (*M* = 6.00, *SD* = 0.00) and School 4 (*M* = 6.00, *SD* = 0.00) displayed significant differences compared to the responses of School 2 (*M* = 5.36, *SD* = 0.674). Significant differences were found between the responses of School 2 (*M* = 5.00, *SD* = 0.632) and School 4 (*M* = 5.88, *SD* = 0.354) for Item 12. The greatest mean difference was found for Item 5: School 1 had an average response indicating disagreement, but School 2 indicated agreement with the item.

School District Comparison of TBEST Categories

An ANOVA was used to analyze each category of items of the TBEST (i.e., Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction; see Table 20). The results showed significant differences between responses to items pertaining to Learning Theory science instruction, $F(3, 447) = 6.002$, $p = .001$.

Table 20

ANOVA of School District Responses to TBEST Categories

		Sum of Squares	*df*	Mean Square	*F*	Sig.
Learning Theory	Between groups	9.723	3	3.241	6.002	.001
	Within groups	241.372	447	0.540		
	Total	251.095	450			
Confirmatory	Between groups	13.427	3	4.476	1.821	.143
	Within groups	695.437	283	2.457		
	Total	708.864	286			
Hands-on	Between groups	0.366	3	0.122	0.064	.979
	Within groups	228.561	119	1.921		
	Total	228.927	122			

Note. The concepts of Learning Theory, Confirmatory instruction, and All Hands-on All the Time science instruction are concepts used within the TBEST questionnaire (Smith et al., 2014). *Learning Theory* refers to the latest research on science instruction. *Confirmatory* refers to instructional activities used to confirm content taught to students. *All Hands-on All the Time (hands-on)* refers to instructional hands-on activities taking precedence over learning content.

Table 21 displays further analysis with the Bonferonni post hoc test. The difference between School 1 (M = 5.53, SD = .65) and School 2 (M = 5.19, SD = .73) on Learning Theory science instruction items accounts for significance found with the ANOVA on TBEST item categories (Table 20).

Table 21

Bonferroni Multiple Comparisons of Learning Theory Responses (N = 41)

	School	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
					Lower	Upper
School 1	2	.339*	.094	0.002	0.09	0.59
	3	.198	.094	0.218	−0.05	0.45
	4	−.017	.103	1.000	−0.29	0.26
School 2	1	−.339*	.094	0.002	−0.59	−0.09
	3	−.140	.094	0.826	−0.39	0.11
	4	−.355*	.103	0.004	−0.63	−0.08
School 3	1	−.198	.094	0.218	−0.45	0.05
	2	.140	.094	0.826	−0.11	0.39
	4	−.215	.103	0.225	−0.49	0.06
School 4	1	.017	.103	1.000	−0.26	0.29
	2	.355*	.103	0.004	0.08	0.63
	3	.215	.103	0.225	−0.06	0.49

Note. *The mean difference was significant at the .05 level.
The concept of Learning Theory science instruction is from the TBEST questionnaire (Smith et al., 2014).
Learning Theory refers to the latest research on science instruction.

The alignment of beliefs on science instruction can be presented through the descriptive statistics of each item for the overall population of the study (see APPENDIX C: SCHOOL VARIANCES ON TBEST ITEMS). The population within the school district averaged a score reflecting agreement on all of the Learning Theory science instruction items (i.e., Items 3, 6, 7, 9, 11, 12, 14, 15, 17, 18, and 21). Item 14 (*M* = 4.88, *SD* = 0.748) and Item 15 (*M* = 4.76, *SD* = 0.943) were the two lowest average scores of agreement for Learning Theory science instruction items.

There was a mixture of average responses to items dealing with Confirmatory science instruction (i.e., Items 1, 2, 5, 10, 16, 19, 20; Table 17). For Item 1 (*M* = 4.63, *SD* = 1.260), Item 2 (*M* = 4.37, *SD* = 1.428), and Item 10 (*M* = 4.66, *SD* = 1.109), on average, the overall study population indicated agreement with the statements. For Item 5 (*M* = 3.85, *SD* = 1.236), Item 16 (*M* = 2.24, *SD* = 1.067), Item 19 (*M* = 3.83, *SD* = 1.358), and Item 20 (*M* = 2.15, *SD* = 1.174), on average, the overall study population indicated disagreement with the statements.

For items dealing with All Hands-on All the Time science instruction (i.e., Items 4, 8, and 13), on average, the overall study population disagreed with the questionnaire statements (Table 18). Item 4 (*M* = 3.51, *SD* = 1.381), Item 8 (*M* = 2.73, *SD* = 1.342), and Item 13 (*M* = 2.68, *SD* = 1.254) all showed mean scores below 4, indicating disagreement with those item statements.

ACT Data

ACT Science data were collected from each of the schools except for School 4. School 4 began operating in the 2013–2014 school year. The first cohort to attend the school all four years of its existence will be the 2017 graduating class. As a result, inconsistencies existed in School 4's ACT data; the available data were not representative of School 4's current population. Thus, the decision was made to exclude the ACT data for School 4.

ACT Science scores were collected from School 1, School 2, and School 3 on an individual student basis. The demographics included in the data set were gender and year of graduation. Each of the data sets represented ACT Science scores of students taking the ACT during their junior year of high school. Because of requirement by the governing state board of education, each school was required to have 95% of their junior class populations take the ACT assessment. The results presented include data from the overall population in the study as well as breakdowns by school.

Composite Science Scores

For the overall study population, the average ACT Science score was just under 20 out of a possible score of 36 (ACT, Inc., 2016a). School 2 had the highest ACT average followed by School 3 and School 1. All three school had a similar population of about 1200 students who took the ACT. The range between the mean scores of the three schools was 0.71. (See Table 22).

Table 22

ACT Science Results

	N	Mean	Standard Deviation (*SD*)
Overall	3,596	19.51	4.349
School 1	1,220	19.22	4.528
School 2	1,173	19.93	4.240
School 3	1,203	19.39	4.239

Graduating Cohort

The ACT Science results can be categorized by graduating cohort. For School 1, School 2, and School 3, three ACT Science results are presented for three different graduating cohorts (Table 23). For the overall study population, an increase in average school ACT Science scores appeared for the 2015 (M = 19.16, SD = 4.341) and 2016 cohorts (M = 19.45, SD = 4.501), compared to the 2017 cohort (M = 19.94, SD = 4.154).

Table 23

Graduating Cohort ACT Science Results

	Graduating Cohort	N	Mean	Std. Deviation
Overall	Class of 2015	1203	19.16	4.341
	Class of 2016	1241	19.45	4.501
	Class of 2017	1152	19.94	4.154
School 1	Class of 2015	426	18.94	4.406
	Class of 2016	431	18.78	4.765
	Class of 2017	363	20.07	4.270
School 2	Class of 2015	413	19.19	4.251
	Class of 2016	395	20.25	4.230
	Class of 2017	365	20.41	4.137
School 3	Class of 2015	364	19.37	4.363
	Class of 2016	415	19.37	4.358
	Class of 2017	424	19.41	4.017

Note. ACT Science composite score was out of a possible score of 36.

The ANOVA between cohorts of the population showed the differences between graduating cohorts were significant, $F(2, 3593) = 9.674$, $p < .001$ (Table 24).

Table 24

ACT Science ANOVA Comparison between Cohorts

	Sum of Squares	*df*	Mean Square	*F*	Sig.
Between Groups	364.193	2	182.097	9.674	.000
Within Groups	67628.660	3593	18.822		
Total	67992.853	3595			

Note. Comparison between School 1, School 2, and School 3.
Dependent variable: ACT Science score

This analysis was followed with a Bonferonni post hoc test to determine specific relationships between cohorts (Table 25). The post hoc revealed a significant increase in average from the 2017 cohort (M =19.94, SD = 4.154) in comparison to both the 2016 (M = 19.45, SD = 4.501) and 2015 cohorts (M = 19.16, SD = 4.341). Further analysis was conducted within each of the participating schools with an ANOVA on ACT Science scores with graduation year as the independent variable (Table 26). The ANOVA was followed by the Bonferroni post hoc test to determine specific significant differences between cohorts of each school (Table 27).

Table 25

Bonferroni Post Hoc Test of Comparisons Between Cohorts

Graduation Year	Graduation Year	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
					Lower	Upper
Class of 2017	Class of 2015	.779*	.179	.000	.35	1.21
	Class of 2016	.489*	.177	.018	.06	0.91

Note. * The mean difference was significant at the 0.05 level.
Dependent variable: ACT Science score

Table 26

ACT Science ANOVA Between Cohorts of each School

School		Sum of Squares	*df*	Mean Square	*F*	Sig.
School 1	Between groups	381.908	2	190.954	9.442	.000
	Within groups	24613.779	1217	20.225		
	Total	24995.688	1219			
School 2	Between groups	347.974	2	173.987	9.822	.000
	Within groups	20724.866	1170	17.714		
	Total	21072.841	1172			
School 3	Between groups	.400	2	.200	0.011	.989
	Within groups	21598.634	1200	17.999		
	Total	21599.034	1202			

Note. Comparison between the 2015, 2016, and 2017 cohorts for School 1, School 2, and School 3.
Dependent variable: ACT Science scores

Table 27

Bonferroni Post Hoc Test between Cohorts for each School

	Graduation Year	Graduation Year	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Lower	Upper
School 1	2015	2016	0.155	.307	1.000	−0.58	0.89
		2017	−1.138*	.321	0.001	−1.91	−0.37
	2016	2015	−0.155	.307	1.000	−0.89	0.58
		2017	−1.292*	.320	0.000	−2.06	−0.52
	2017	2015	1.138*	.321	0.001	0.37	1.91
		2016	1.292*	.320	0.000	0.52	2.06
School 2	2015	2016	−1.057*	.296	0.001	−1.77	−0.35
		2017	−1.215*	.302	0.000	−1.94	−0.49
	2016	2015	1.057*	.296	0.001	0.35	1.77
		2017	−0.158	.306	1.000	−0.89	0.58
	2017	2015	1.215*	.302	0.000	0.49	1.94
		2016	0.158	.306	1.000	−0.58	0.89

Note. * The mean difference is significant at the .05 level.
Dependent variable: ACT Science scores

When comparing individual schools' 2015, 2016, and 2017 graduating cohorts, a significant difference was found between School 1 cohorts, $F(2, 1217) = 9.442$, $p < .001$, and School 2 cohorts, $F(2, 1170) = 9.822$, $p < .001$. No difference was discovered between the graduating cohorts of School 3.

The School 1 post hoc test showed a significant difference between the ACT Science results of the 2017 cohort (*M* = 20.07, *SD* = 4.270) and both the 2015 (*M* = 18.94, *SD* = 4.406), and 2016 (*M* = 18.78, *SD* = 4.765) cohorts. For School 2, a significant difference was found among the performances of the 2015 cohorts (*M* = 19.19, *SD* = 4.251), the 2016 cohorts (*M* = 20.25, *SD* = 4.230), or the 2017 cohorts (*M* = 19.41, *SD* = 4.017). No significant difference was found between the 2016 and 2017 graduating cohorts of School 2.

ACT Science and TBEST Results

Two analyses were completed to compare ACT Science results of each school with corresponding TBEST responses. The first analysis used the average responses to the item categories of the TBEST questionnaire (i.e., Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction). Student ACT Science composite scores were compared to these average TBEST responses (Table 28).

The second analysis was a comparison between student ACT Science composite scores and the level of alignment between responses to the TBEST questionnaire categories (i.e., Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction). The analysis used the average variance within responses of each science department.

Table 28

Pearson Correlation Between ACT Science and TBEST Categories

		Mean Response	Variance Within Responses
Learning Theory	Pearson Correlation	-0.064^{**}	.001
	Sig. (2-tailed)	0.000	.950
Confirmatory	Pearson Correlation	-0.040^{*}	$.035^{*}$
	Sig. (2-tailed)	0.017	.036
Hands-on	Pearson Correlation	–0.003	$.055^{**}$
	Sig. (2-tailed)	0.839	.001

Note. *N* = 3,596.
** Correlation is significant at the .01 level (2-tailed).
*Correlation is significant at the .05 level (2-tailed).
The concepts of Learning Theory, Confirmatory instruction, and All Hands-on All the Time science instruction are concepts used within the TBEST questionnaire (Smith et al., 2014). *Learning Theory* refers to the latest research on science instruction. *Confirmatory* refers to instructional activities used to confirm content taught to students. *All Hands-on All the Time (hands-on)* refers to instructional hands-on activities taking precedence over learning content.

Significant results were discovered throughout the analysis between TBEST categories and ACT Science achievement. The results demonstrated a significant relationship between ACT Science achievement and the variables of mean response to Learning Theory science instruction items, mean response to Confirmatory science instruction items, variance between responses of Confirmatory science instruction items, and variance between responses to All Hands-on All the Time science instruction items.

The results, however, showed no correlation between ACT Science achievement and average responses to Learning Theory science instruction items, $r(3594) = -.064$,

$p < .001$. For Confirmatory science instruction items, neither the average response for science departments, $r(3594) = -.040$, $p = .017$, nor the variance between responses, r(3594 = 0.35, $p = .036$, showed any correlation with ACT Science achievement. This trend held true for All Hands-on All the Time science instruction items. The variance between responses for each science department had no correlation with ACT Science achievement, $r(3594) = -.040$, $p = .017$.

Summary

This chapter provided the data used to answer the research questions of the study. The data presented were collected from the TBEST questionnaire and ACT Science results from four schools within a single district. Because School 4 first opened for the 2013–2014 school year, ACT Science composite scores were not considered to avoid the inconsistencies among their cohorts the first two years after opening. Data were also presented on the demographics of the participating district to provide the context of the study.

TBEST questionnaire results were presented by individual item responses, school science department average responses, and the average responses from the entire population of the study. The individual responses indicated all participants showed high agreement with TBEST items that were aligned with Learning Theory science instruction. In addition, the school science department average responses revealed alignment in science instructional beliefs with the Learning Theory science instruction items when compared to items that were aligned with Confirmatory science instruction and All Hands-on All the Time science instruction.

Within the overall population, three items from the TBEST demonstrated significant differences in average responses. For two of the three items (Item 7 and Item 12), the differences occurred in the degree of agreement with the TBEST items. In addition, Item 5 showed significant difference in the degree of agreement with the TBEST items. For Item 5, School 1 average responses were in disagreement with item 5, while for School 2 average responses were in agreement with Item 5. The results from item 5, item 7, and item 12 were consistent with the overall variances found between schools when considering the existing categories of TBEST items. Lower variance (alignment of beliefs) was found with Learning Theory science instruction items, and higher variances were found with Confirmatory science instruction and All Hands-on All the Time science instruction items.

The demographics of the school district revealed a consistently growing population enrolling into schools in the school district each year. The school district also proved to have many of the same individuals in leadership positions over the last several years. These individuals include board members and the director of schools. The schools in the study all showed similar ethnic/racial breakdowns as well as the overall enrollment.

Similar ACT Science composite scores were found among students at the schools for the previous three years. Considering ACT Science results of graduating cohorts within the school district, the school district overall showed significant differences between the 2017 cohort and both the 2015 and 2016 cohorts. Similar results were found within the graduating cohorts at each school.

The final analysis compared TBEST responses to ACT Science composite scores. The average responses and alignment of beliefs for each TBEST category (i.e., Learning Theory, Confirmatory instruction, and All Hands-on All the Time science instruction) were compared to student achievement on ACT Science. Overall significant results were observed; however, no correlations were found between each of the variables. A discussion of these results is presented in Chapter V.

CHAPTER V

DISCUSSION

Introduction

This study focuses on the ACT Science achievement of a school district and the beliefs about effective science instruction of teachers in schools in the school district. The purpose is to provide a foundation for measuring science instructional beliefs, determine alignment of those beliefs in science departments and a school district, and identify any existing relationships between instructional beliefs and ACT science achievement. Chapter IV provided results from the methods presented in Chapter III. Chapter V discusses the results of the study and the conclusions that were made based on the results of the study.

Chapter V is divided into four main sections: (a) discussion of results, (b) answering the research questions, (c) implications of the study, and (d) conclusions. Each of the sections synthesize the background research, methodology, and results of this study. The discussion of results provides explanations of the results presented in Chapter IV. The discussion includes sections on beliefs about science instruction, alignment of instructional beliefs, ACT results, and the contributing factors of school and school district demographics.

Answers to the research questions are justified using previous findings in literature as well as using the data collected for this study. The implications section focuses on how the findings of the study can enhance all stakeholders involved in the study as well as how the study contributes to education literature. Because the results focus on a single school district, many of the implications are directly geared toward the participants in the study. The conclusion of the chapter provides overall takeaways from the study. The section includes suggestions for future research. These suggestions include ways to improve this study as well as ways to build upon the results. The chapter closes with a summary.

Discussion

Beliefs about Science Instruction

The TBEST instrument provides a view on how teacher beliefs align with different aspects of science instruction (Smith et al., 2014). The aspects of science instruction measured include Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction. Responses from participating teachers about science instruction beliefs has been linked to practices in the classroom (Brickhouse, 1990; Cronin-Jones, 1991; Lederman et al., 2002; Luft & Roehrig, 2007; Lumpe et al., 2000; Magnusson et al., 1999; Sampson et al., 2013; Smith et al., 2014; Wong & Luft, 2015; Yerrick et al., 1997). However, barriers within schools still exist that can impede teachers from putting instructional beliefs into practice (Lumpe et al., 2000; Yerrick et al., 1996). For this study, beliefs held by teachers were assumed to inform the likely practices in the classroom. Teacher beliefs were measured and analyzed using the TBEST instrument.

The TBEST developers suggested categorizing responses as either *high* or *low* on Learning Theory science instruction, Confirmatory science instruction, and All Hands-on

All the Time science instruction items (Smith et al., 2014). Smith et al. indicated the ideal responses from participants were high scores on Learning Theory science instruction items, and low scores on both Confirmatory science instruction and All Hands-on All the Time science instruction items. Because of the varied responses, two other classifications were added: *slightly high* and *slightly low*, addressing the closeness in agreement and disagreement among participants. The scale used in the TBEST required participants to either agree or disagree; neutral responses were not allowed.

The results from the TBEST indicated an alignment of instructional beliefs with Learning Theory throughout each school. On average, the participants in the study agreed with the Learning Theory science instruction items (Table 29). In contrast, only 11 participants agreed on average with Confirmatory science instruction items, and seven with All Hands-on All the Time science instruction items.

Table 29

Number of Participants in Agreement With TBEST Item Categories (N = 41)

	Learning Theory	Confirmatory	Hands-on
Number of participants in agreement	41	11	7

Note. The concepts of Learning Theory, Confirmatory instruction, and All Hands-on All the Time science instruction are concepts used within the TBEST questionnaire (Smith et al., 2014). Learning Theory refers to the latest research on science instruction. Confirmatory refers to instructional activities used to confirm content taught to students. All Hands-on All the Time (hands-on) refers to instructional hands-on activities taking precedence over learning content.

Of the 41 participants, 27 scored at least slightly high on only the Learning Theory science instruction items (Table 30), consistent with the ideal description for science instruction presented in the TBEST manual (Smith et al., 2014). The other 14 participants were classified into three other categories: those who scored in agreement with both Learning Theory science instruction and Confirmatory science instruction; those who scored in agreement with both Learning Theory science instruction and All Hands-on All the Time science instruction; and those who scored in agreement with all three types of instruction.

Table 30

Classification of Participants Based on TBEST Category Responses

	Learning Theory	Learning Theory & Confirmatory	Learning Theory & All-Hands-on	All Three
School 1 (*N* = 11)	7	2	1	1
School 2 (*N* = 11)	7	1	2	1
School 3 (*N* = 11)	6	4	0	1
School 4 (*N* = 8)	7	0	0	1

Note. The concepts of Learning Theory, Confirmatory instruction, and All Hands-on All the Time science instruction are concepts used within the TBEST questionnaire (Smith et al., 2014). Learning Theory refers to the latest research on science instruction. Confirmatory refers to instructional activities used to confirm content taught to students. All Hands-on All the Time (hands-on) refers to instructional hands-on activities taking precedence over learning content.

In terms of the beliefs of teachers at each of participating schools, School 4 showed the highest average of participants responding in high agreement solely for

Learning Theory science instruction items. In contrast, School 2 had the most participants who were in agreement with Confirmatory science instruction and All Hands-on All the Time science instruction. These result indicated an overall strong sense of science Learning Theory in the participating schools; the strongest results were displayed by School 4 (M = 5.55, SD = 0.17).

Alignment of Instruction Beliefs

The categorization of teacher beliefs not only is an indication of a strong sense of science Learning Theory, but also of alignment among individuals in the participating schools and school district. All schools in the study averaged scores of agreement on Learning Theory science instruction items (M = 5.39, SD = 0.38) and disagreement on both Confirmatory science instruction (M = 3.68, SD = 0.74) and All Hands-on All the Time science instruction items (M = 2.98, SD = 1.12).

The levels of agreement and disagreement scored by participants from each school indicated a surface level alignment of beliefs among participants. Scores were classified into *high* and *low* (i.e., agree or disagree), as recommended by the TBEST authors (Smith et al., 2014). *High* and *Low* classifications reflect the average response of participants on items aligned with Learning Theory, Confirmatory, and All Hands-on All the Time science instruction. Because the classification is an aggregate of responses to all items of the TBEST categories, *High* and *Low* only provide a surface level analysis.

The scores revealed 67% of the population in the study scored high on Learning Theory science instruction items and low on both Confirmatory science instruction and All Hands-on All the Time science instruction items. For School 1 and School 2, 64% of the participants scored high only on Learning Theory science instruction items. For School 3, 55% of the participants scored high on Learning Theory science instruction items only. For School 4, 88% of the participants scored high only on Learning Theory science instruction items; however, the school had three fewer participants than did the other schools.

The variances among responses were considered when determining alignment of instructional beliefs. Variances among responses of participants of individual schools generally were lower than the overall study population variance. This finding indicates that individuals within each school held beliefs more similar to one another than to the overall population. This especially held true for Learning Theory science instruction items. Items dealing with Confirmatory science instruction and All Hands-on All the Time science instruction typically showed more variance in their responses. This was consistent with the overall classification of participant beliefs, as indicated by the high agreement scores by each individual on Learning Theory science instruction items. When comparing each school, only three items were significantly different among school science departments. These items included one Confirmatory science instruction item (Item 5) and two Learning Theory science instruction items (Items 7 and Item 12).

School 1 and School 3 did not have aligned perspectives regarding Item 5, which concerned whether teachers should explain a concept to students before having them consider evidence that relates to the concept, $F(3, 37) = 3.970$, $p = 0.015$. School 1 on average disagreed with the statement ($M = 3.36$, $SD = 1.03$); School 3 showed average agreement ($M = 4.82$, $SD = 1.17$).

School 1 and School 4 showed significantly different responses compared to School 1 on Item 7, which concerned whether teachers should ask students to support their conclusions about a science concept with evidence. This item showed a significant difference between schools because of the degree of agreement with the item. For both School 1 and School 4, all participants strongly agreed with the statement (School 1, *M* = 6.00, *SD* = 0.00; School 4, *M* = 6.00, *SD* = 0.00); School 2 agreed with the statement but to a lesser degree (*M* = 5.36, *SD* = 0.67).

Item 12 stated that students should use evidence to evaluate claims about a science concept made by other students. The significant difference in responses occurred between School 2 (*M* = 5.00, *SD* = 0.63) and School 4 (*M* = 5.88, *SD* = 0.91). Similar to the finding for Item 7, the difference in responses was because of different degrees of agreement. Items 7 and 12 contrasted with Item 5—the average responses conflicted: School 1 disagreed with the item, and School 3 agreed with the item.

ACT Results

Each of the participating schools demonstrated similar 3-year averages with ACT Science composite results (School 1, *M* = 19.22, *SD* = 4.53; School 2, *M* = 19.93, *SD* = 4.24; School 3, *M* = 19.39, *SD* = 4.24). The ACT Science results, however, became more revealing when analyzed by graduating cohort. For each school, the average scores increased from the 2015 cohort through the 2017 cohort. The overall averages for cohorts between schools demonstrated a significant difference between the 2017 cohort and both 2015 and 2016 cohorts. This indicates a trend of increasing ACT Science composite scores across the district.

In particular, School 1 was primarily responsible for the significant difference between cohort averages. School 1 demonstrated the largest difference in means between the 2017 cohort and the 2015 and 2016 cohorts. For School 2, a significant difference observed only between the 2017 and 2015 cohorts. School 3 showed no significant differences between ACT Science composite scores between any of its cohorts. These results indicate differences existed among the schools in the study and possibly between their approaches to ACT Science improvement. The extent of these differences could also be explained by myriad other variables, ranging from school demographics to specific initiatives taken by each school to address ACT Science achievement.

The final analysis conducted with the ACT Science composite scores involved the TBEST questionnaire results. This analysis compared two aspects of responses to the TBEST questionnaire to the ACT Science composite scores. The analyses included the average responses to each category of items (i.e., Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction) and the alignment of beliefs for each school among each category. Both analyses showed significant aspects; however, the results indicated no relationship between ACT Science scores and either average response to TBEST items or the alignment of instructional beliefs.

These results do not indicate any particular conclusion. Instead, they are more a reflection of a defining limitation to the study: sample size. The sample size consisted of four schools, only three of which were used for the ACT analysis. Although comparing ACT Science scores with the beliefs of science departments was appropriate for this study, any concluding remarks on this topic would have to extend to a future study using a larger sample size of schools. Further, the sample size would also have to include schools with a wider range of ACT Science performance than the three included in this study. The range could include schools with higher or lower performance on ACT Science; the goal is to have contrasting ACT Science achievement within the sample size.

School and District Demographics

The demographics of the school district and schools showed a growing population in the geographical location of the school district. The annual enrollment data indicated the population of school district was growing by at least 2% each year with the exception of 2014–2015. The sharp decline in enrollment growth that year can be explained by a new school opening in a K–6 feeder school district. This K–6 school district was separate from the school district participating in this study. The population of the K–6 school district will eventually filter into the secondary schools of the participating school district.

The leadership of the school district has demonstrated consistency by maintaining many of the same individuals in leadership positions over a period of time. Four members of the current school board of education for the school district had been serving in their position for the previous four school years. The current director of schools had been in the position since the start of the 2012–2013 school year. Prior to that school year, the same individual functioned as the school district's curricula and instructional superintendent. As a result, this individual was in a position of policy and instructional leadership for an extended time.

Much of the policy, curricula, and instructional decisions made by leaders directly affect teachers and their ability to put their instructional beliefs into practice (Lumpe et al., 2000). Lee and Luft (2008) discussed the importance of teachers developing a knowledge base for the resources they receive (e.g., curricula, technology, new instructional methods) in order to deliver the best instruction using those resources. The school district and school leaders in this case were directly responsibility for the professional development of teachers as instructional professionals. The correct steps in teacher training and development, especially in focused area such as the ACT, can result in positive growth in those areas (Lee & Luft, 2008). Missteps in the training and development of teachers can also have negative effects (Lee & Luft, 2008).

The school leaders in the participating school district had the autonomy to make decisions on how the professional development and training of teachers took place. However, much of the training was dependent upon the initial directives provided by school district leaders. Again, considering the influence that professional development and teacher training can have on use of instructional resources (Lee & Luft, 2008), the decisions leaders make can have profound effects on the ability of teachers to put their instructional beliefs into practice.

In this study, science instruction in the school district was taking place in schools serving similar populations of students. The four schools in the study all served ethnic/racial populations consisting of a majority of White students, followed by Black students and other groups. School 3 had a larger percentage of Hispanics, compared to the other three schools. Further variations existed regarding the percentages of the population that were economically disadvantaged. School 3 had the largest percentage of economically disadvantaged students, followed by School 1.

The similarities between schools could ultimately factor into the similarity in ACT Science performance. In addition, the breakdown of ethnicity, economic status, money spent for each student, and overall enrollment of each school could be considered contributing factors that could affect the average performance on ACT Science for each school. These factors provide the same opportunities and barriers when it comes to reaching students instructionally and preparing them for the ACT Science assessment. For instance, enrollment numbers alone can forecast the emergence of larger science departments. In this study, the targeted population at each school consisted of 15 teachers in the science departments. Larger science departments have more teachers for collaboration, more course opportunities for students, and a potentially wider range of course levels offered.

However, teachers at larger schools and school districts can also face barriers. For example, providing adequate support for individual teachers, developing individualized instruction for students, and providing similar instruction to all students within the school district are barriers that hamper success when serving large populations of students. Growing populations can also complicate how school districts are organized to educate children. At the time of this study, this particular school district had seen consistent growth over the past 15 years, serving nearly 20,000 more students than it served 15 years ago. Even within the previous decade, the school district experienced an enrollment increase of 10,000 students.

Despite the changing dynamics of the school district, consistency in school district leadership and school management may have contributed to the similarities between schools participating in the study. As the school district grew, so did the number of schools. One example of this occurred with the addition of School 4 to the school district at the start of the 2013–2014 school year. The addition of this school maintained consistency of student enrollment at other schools.

School district leaders are responsible for school district policy and initiatives. These policies and initiatives are distributed to schools in the school district and adapted to fit the needs of students. The strength of the policy or initiative and the manner in which it is implemented should reflect how the policy affects teachers and students in classrooms. Science instruction within the school district would be a singular focus in running the school district. As a result, overarching instructional policy is more common than policy specific to science education.

In consideration of the ACT Science scores and responses to the TBEST questionnaire, an argument can be made that science instruction was consistent in the way in which it is delivered throughout the school district. The argument was derived from the consistency of leadership, ACT Science results, and TBEST questionnaire data.

Research Questions

Research Question 1

Research Question 1 was “Do teacher beliefs about science instruction align with Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction as measured by the TBEST questionnaire?” To address the first research question, data from the TBEST questionnaire were collected from a single school district. Within the school district, science departments of four different schools participated in the study. Individual participant responses were analyzed and classified into the categories of *high*, *slightly high*, *slightly low*, and *low* for each TBEST item associated with Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction. High response scores for any item indicated agreement with the instructional statement, and low indicated disagreement.

Teachers who are fully aligned with current science Learning Theory should average high on the Learning Theory items while averaging low on the Confirmatory science instruction items and All Hands-on All the Time science instruction items (Smith et al., 2014). All participants averaged high and slightly high responses to the Learning Theory science instruction items on the TBEST. Of the 41 participants, 27 scored high on Learning Theory science instruction items only. Those participant who did not fall into this classification were classified as high on both Learning Theory science instruction and Confirmatory science instruction ($N = 7$), high on Learning Theory science instruction and All Hands-on All the Time science instruction ($N = 3$), or high on items from all three categories ($N = 4$).

Research Question 2

Research Question 2 was "Do science teachers in a science department hold the same beliefs about science instruction?" This research question was addressed using descriptive data from the TBEST for individual participants, school average responses, and the overall average response to items on the questionnaire. In particular, the variances found among responses from each school were compared to the overall variance for the population. The variance between responses within the individual science department should reflect the alignment of beliefs about science instruction. Research Question 2 was addressed with the classifications used for Research Question 1.

The variances between individuals within the participating schools was generally lower than the population variance on Learning Theory items. This was with exception to School 3 that showed higher variance than the population on Learning Theory items. These results indicate science departments of each school have more aligned beliefs about science instruction associated with the concepts behind Learning Theory science instruction (Smith et al., 2014). Further, School 3 can be identified as having less aligned beliefs among participants about science instruction in comparison to the other three schools.

If variance for the Confirmatory science instruction and All Hands-on All the Time science instruction items are considered, the mean of each school would be expected to indicate disagreement with the statements (Smith et al., 2014). Beyond the average response, variance for each of these TBEST category should be comparable to that of Learning Theory. For both Confirmatory and All Hands-on All The items, variances were much larger in comparison to Learning Theory. This indicates participants of each school to have varying opinions on science instruction categorized as Confirmatory and All Hands-on All the Time resulting in varying responses to the associated items.

School 1 and School 4 showed lower variances compared to the overall population variance on Confirmatory items. School 2 and School 3 showed variances higher than the population variance on these instructional items. The individual participant classification data were consistent with this finding. School 3 for example, had four participants response on average in agreement and seven in disagreement on Confirmatory items.

For All Hands-on All the Time science instruction items, School 1 and School 3 showed lower variance compared to the overall population. The overall variance on All Hands-on All the Time items, however, was lower than Confirmatory items. This suggests participants of each school to have more aligned beliefs on All Hands-on All the Time items than Confirmatory items.

Despite the findings in Research Question 1, the variance among TBEST items suggests beliefs about science instruction are not aligned between participants of each school. Learning Theory items demonstrated the most alignment of beliefs, however, compete alignment would be indicated with a variance of zero. Item 7 ("Teachers should ask students to support their conclusions about a science concept with evidence") was the only TBEST item to show a variance of zero between participants in a school. Participants in School 1 and School 4 displayed complete alignment on this item by responding with strong agreement (M = 6.00, SD = 0.00).

From this perspective, each individual would have to score each TBEST item identically for no variance to exist, indicating completely aligned beliefs. This was not considered a realistic expectation. Thus, it was worth factoring in the results from

Research Question 1 and the classifications of each participant. This analysis revealed a certain degree of aligned beliefs among participants and school science departments. The results from Research Question 2 fine-tuned the classifications of each participant to show that there were still varying levels of alignment for each TBEST items. For example, for the Learning Theory science instruction items, although each participant agreed overall with Learning Theory science instruction items, participants individually still disagreed with some of the items. This indicated a certain level of unaligned beliefs among participants regarding how science should be instructed.

Research Question 3

Research Question 3 was “Do science teachers at different schools in one school district hold the same beliefs about science instruction?” The concept of alignment between science departments within a single school district was further investigated statistically and compared to Research Question 2. The groupings that existed between science departments allowed for a certain degree of hypothesis testing in consideration of how each school responded to TBEST items. The results from the hypothesis testing showed a failure to reject the null hypothesis that teachers within the same school district do not hold the same instructional beliefs about science. This was because of three items on the TBEST that showed statistically different responses.

In the initial analysis regarding significant relationships between the participating schools, Item 5, Item 7, and Item 12 showed significant differences among science departments (see APPENDIX D: SCHOOL TBEST ANOVA RESULTS). Post hoc comparisons using a Bonferroni test indicated a significant difference in responses on

Item 5 between School 1 and School 3, on Item 7 between School 2 and both School 1 and School 4, and on item 12 between School 2 and School 4. Item 5 was a Confirmatory science instruction item, and both Item 7 and Item 12 were Learning Theory science instruction items.

For item 5, the significant difference between School 1 (M = 3.36, SD = 1.027) and School 3 (M = 4.82, SD = 1.348) was the difference between an average agreement and disagreement on the item. On average, School 1 disagreed with the Confirmatory science instruction item; on average, School 3 agreed. The significant difference on Item 7 and Item 12, however, indicated a difference in the level of agreement. For Item 7, both School 1 and School 4 responded in strong agreement with the item (M = 6.00, SD = 0.00); School 2 responded with a different degree of agreement (M = 5.36, SD = 0.674). Item 12 was similar: Both School 2 (M = 5.00, SD = 0.632) and School 4 (M = 5.88, SD = 0.354) agreed with the item.

The type of items that displayed significant differences between responses among schools makes a strong argument for an overall level of alignment in science instructional beliefs. Of the 21 items on the TBEST, a single Confirmatory science instruction item was determined to have a significant level of disagreement among two of the participating schools; this disagreement was determined to be the difference between agreeing and disagreeing with the item. For Item 7 and Item 12, significant differences existed, but the differences were due to the degree of agreement schools had with the Learning Theory items.

Although Research Question 3 was originally addressed using hypothesis testing, the data analysis did not allow for a traditional response. Significant differences among TBEST items were observed, but the results do not amount to the conclusion that the schools are or are not aligned in their beliefs about science instruction.

Research Question 4

Research Question 4 was “What relationships exist between science departments with higher belief scores compared to Learning Theory and ACT Science scores?” The relationships between ACT Science achievement and science instructional beliefs within a school was addressed using ACT Science results, average responses to TBEST items, and variances for Learning Theory science instruction, Confirmatory science instruction, and All Hands-on All the Time science instruction TBEST categories from three of the participating schools. The variables were tested for correlation. Results indicated several significant findings. However, for each finding, no correlational relationship existed between variables. This resulted in failure to reject the null hypothesis that no differences existed in student ACT Science achievement within schools that scored higher on Learning Theory science instruction items on the TBEST.

The analysis of this data was hindered by two factors. The first factor was the small number of schools participating in the study. A larger sample of school may have revealed potential correlations or trends concerning the variables of ACT Science achievement and beliefs about science instruction. The second factor was the need to recruit schools with contrasting ACT Science achievement and contrasting perspectives on science instructional beliefs. School 1, School 2, and School 3 all had similar ACT

Science results and TBEST responses. It was, therefore, difficult to draw anything but inconclusive results from the data collected.

Implications of Study

This study serves several purposes for the specific school district and contributes to research literature for the field of science education. The implications go beyond increasing ACT Science scores. Results from this study and similar future studies can help improve all science learning and instruction. This can be accomplished by increasing the understanding of school and school district leadership about the needs of science teachers. Creating this understanding starts with the measurement of science teachers' beliefs and understanding of science instruction.

This study provided a baseline of science teacher beliefs about current science instructional Learning Theory. Although the majority of teachers participating scored high on TBEST Learning Theory science instruction items, the school district could employ the instrument itself in the future for progress monitoring or to determine the worth of professional development efforts, new resource investments, and new science initiatives.

Results regarding the alignment of teacher beliefs can also serve the school district and participating schools. Reporting the variances that existed among individuals and overall science departments provides a better understanding of where teachers stand from a collaborative standpoint. The school district can utilize these measurements for progress monitoring in regards to collaborative teaming. The school district can also use the study's methodology to determine the needs of individual science departments and locate individuals who may be outside the norm regarding beliefs about science instruction. That is, schools can determine those individuals who do not hold beliefs aligned with current science Learning Theory. Understanding who these individuals are can help guide a school or school district in providing for the individual needs of teachers in order to induce the highest level of instruction to students.

The school district in the study showed statistical evidence of a significant increase in ACT Science achievement over the previous three years. These results could confirm any investments, professional development efforts, or initiatives that were put in place. If nothing had been done to improve ACT Science achievement, this increase in achievement could be grounds to determine what individual schools were doing to improve student scores.

Finally, from a methodology standpoint, this study enhanced the use of the TBEST survey in a mode for which it was not originally designed. Measuring the alignment of beliefs using existing variances for each item can inform schools about not only whether their teachers were instructionally in agreement with science Learning Theory, but also if teachers were instructionally in agreement with one another.

Recommendations

Several recommendations emerged from the findings. The first recommendation derived from this study relates to the finding that the majority of the participants agreed with the Learning Theory science instruction items on the TBEST. Based on these results, it is worth further investigation to determine what barriers exist between science teachers' instructional beliefs and instructional practices taking place in classrooms. If the eventually goal is to enhance student achievement in science, especially in regards to ACT Science scores, teachers should be provided the necessary means to put instructional beliefs aligned with science Learning Theory into action.

For the school district participating in the study, it is evident that three schools within the study had similar ACT Science scores. The similarities of the schools extended to their demographics and annual enrollment numbers. Demonstrating that participants from the schools held similar beliefs about science instruction highlights a need for further investigation into the needs of science teachers. Considering the similarities among teachers found in this study, teachers may have common needs to advance their instruction. As a result, the school district could potentially derive simply policy changes that could benefit a large number of science teachers. Policy changes could include anything from science-specific professional development to physical resources that could be used in classrooms.

Conclusion

Although no statistically definitive relationships were found between ACT Science achievement and the TBEST questionnaire responses, other statistical findings of worth regarding the ACT Science data were noted. When highlighting the cohorts for the previous three years, results showed evidence of increasing scores for the school district. More specifically, School 1 and School 2 ACT Science scores over the previous three years accounted for this statistically significant improvement.

The ACT Science scores among the three schools participating within the school district were similar in their 3-year average. Considering the other similarities found between the schools and TBEST questionnaire responses, it is worth noting again the need for further investigation. Larger sample sizes of schools and more contrast between ACT Science scores could reveal the effects of instructional beliefs about science or the alignment of instructional beliefs on student achievement.

The similarities could also be accounted for by the influence of leadership on instructional practices. All schools in the study were a part of the same school district. The school district itself had consistent leadership. Advancing ACT achievement could result from teacher development implemented by consistent leaders in the school district, affirming Luft and Roehrig's (2007) conclusion that instructional beliefs can be modified over a period of time.

However, it is also fitting to argue that the nature of science itself could contribute to teachers' beliefs about the best mode of instruction. Understanding how science works could be a common factor among science teachers that contributed to the majority of participants responding with agreement to the Learning Theory science instruction items. This explanation would also contribute to the argument that teachers are resistant to influences by leaders to change instructional strategies (Luft, 2001; Yerrick et al., 1997). Teachers who are strongly influenced by the nature of science may not be open to instructional strategies that do not coincide with their personal beliefs (Brickhouse, 1990). As a result, pushing policy or instructional practices onto teachers, such as improving ACT Science scores, could prove difficult.

Ultimately, the results of this study showed that the participating school district contained schools with science teachers who largely held similar instructional beliefs, according to responses on the TBEST questionnaire. This conclusion was complemented by three of the participating schools having similar ACT Science results over the course of the previous three years. However, because of the single snapshot in time of science teacher instructional beliefs, it is difficult to determine if the teachers' beliefs or the alignment of beliefs among teachers and schools contributed to ACT Science achievement. The similar profile of teachers in the school district raises several questions about ACT Science performance:

- If teacher beliefs are largely in agreement with the latest research on science instructional theory, are there barriers that hinder teachers from putting beliefs into action?
- How do instructional strategies in science influence ACT Science achievement?
- With evidence of increasing ACT Science scores, what specific steps has the school district taken toward this improvement?

Future Research

Ideally, the TBEST would be a before-and-after measurement for science professional development (Smith et al., 2014). However, the school district in the study might not benefit from using the TBEST questionnaire in this manner because of the high agreement score found among the majority of participants on Learning Theory science instruction items. The results of this study do, however, set parameters for the alignment of beliefs within the school district (Table 31).

Future studies could consider only those participants who responded ideally to the TBEST questionnaire. In this study, these participants showed high scores on Learning Theory science instruction items and low scores on both Confirmatory science instruction and All Hands-on All the Time science instruction items (Smith et al., 2014). The variance among responses could be used in future studies to determine the level of alignment of beliefs among science teachers. As education continues to evolve and build upon collaboration, this measurement could help identify needs within the science departments of individual schools or even across entire school districts.

Table 31

TBEST Responses with Beliefs Aligned Only to Learning Theory

	Mean	Standard Deviation (*SD*)	Variance
Learning Theory	5.47	0.69	0.48
Confirmatory	3.35	1.62	2.61
Hands-on	2.49	1.31	1.70

Note. The concepts of Learning Theory, Confirmatory instruction, and All Hands-on All the Time science instruction are concepts used within the TBEST questionnaire (Smith et al., 2014). *Learning Theory* refers to the latest research on science instruction. *Confirmatory* refers to instructional activities used to confirm content taught to students. *All Hands-on All the Time (hands-on)* refers to instructional hands-on activities taking precedence over learning content.

The TBEST questionnaire supplies data to measure only a broad aspect of pedagogical content knowledge (PCK). The instrument focuses on best instructional practices for all science courses. However, PCK can still be further categorized into individual disciplines (e.g., biology, chemistry, or physics). Building upon the use of the

TBEST in this study, future researchers could use the TBEST questionnaire with an instrument designed to measure content knowledge of a specific discipline. The purpose of focusing specifically on content is because teachers who are knowledgeable about the content being instructed can adapt instruction to the needs of individual learners more effectively (Heller, Daehler, & Kasowitz, 2004; Magnusson et al., 1999). This combination of the TBEST with a content-based instrument could enhance the use of the TBEST instrument, supplying data specific to science disciplines.

In consideration of the participants in this study, it is likely revisions to the TBEST should be considered to differentiate teachers from one another more accurately. The results of this study indicated a large percentage of the participants held ideal beliefs regarding science instruction (Smith et al., 2014). However, the school district itself recognized the need for improvement on ACT science. An additional investigation into the science instruction of those teacher who scored high in Learning Theory science instruction items and low in both Confirmatory science instruction and All Hands-on All the Time science instruction would be advised as an extension to this study.

In addition, educators need to determine if barriers exist between science instructional beliefs and practice. Again, considering the large portion of participants who responded ideally to the TBEST questionnaire, it would be worth conducting a future study observing the classrooms of these teachers. Only then could results show how instructional practices align with beliefs data gathered from the TBEST instrument.

The coursework in classrooms may also play a role in ACT science achievement (ACT, Inc., 2013; 2015). Future studies could consider the instructional beliefs of teachers of different science courses. Specifically, physics can be addressed to determine why students who include physics in their high school science progression tend to have higher achievement on ACT science (ACT, Inc., 2013). This type of study could provide insight into course pathways for students in secondary education.

REFERENCES

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education*, *22*(7), 665–701. doi:10.1080/095006900050044044

ACT, Inc. (2013). *Science Courses Taken and ACT College Readiness Benchmark Performance in Science*. Retrieved from http://www.act.org/research

ACT, Inc. (2014). *ACT College and Career Readiness Standards-Science*. Retrieved from http://www.act.org/research

ACT, Inc. (2015). *The Condition of College & Career Readiness 2015*. Retrieved from http://www.act.org/research

ACT, Inc. (2016a). *Preparing for the ACT Test*. Retrieved from http://www.act.org /content/dam/act/unsecured/documents/Preparing-for-the-ACT.pdf

ACT, Inc. (2016b). *The Condition of College & Career Readiness 2016*. Retrieved from http://www.act.org/research

Allen, J., & Sconing, J. (2005). Using ACT assessment scores to set benchmarks for college readiness. *ACT Research Report Series, 2005*(3), 1–29. Retrieved from http://files.eric.ed.gov/fulltext/ED489766.pdf

Allen, J., Robbins, S. B., Casillas, A., & Oh, I.-S. (2008). Third-year college retention and transfer: Effects of academic performance, motivation, and social connectedness. *Research in Higher Education*, *49*(7), 647–664. doi:10.1007/s11162-008-9098-3

American Association for the Advancement of Science. (1994). *Science for all Americans: Project 2061*. Oxford, UK: Oxford University Press.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W.H. Freeman.

Banilower, E., Cohen, K., Pasley, J., & Weiss, I. (2010). Effective science instruction: What does research tell us? *Center on Instruction*. Retrieved from http://files.eric.ed.gov/fulltext/ED521576.pdf

Bobek, B., & Zhao, R. (2015). Education and career navigation. In *Beyond Academics: A Holistic Framework for Enhancing Education and Workplace Success* (ACT Research Report Series 2015, vol. 4, pp. 39-51). Retrieved from http://www.act.org/research

Bransford, J. D., Brown, A. L., & Cocking, R. R. (1999). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.

Brickhouse, N. W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education*, *41*(3), 53–62. doi:10.1177/002248719004100307

Brown, A. L. (1975). The development of memory: Knowing, knowing about knowing, and knowing how to know. *Advances in Child Development and Behavior*, *10*, 103–152. doi:10.1016/S0065-2407(08)60009-9

Camara, W., O'Connor, R., Mattern, K., & Hanson, M. A. (2015). Beyond academics: A holistic framework for enhancing education and workplace success. *ACT Research Report Series, 2015*(4), 1–91. Retrieved from http://www.act.org /content/dam/act/unsecured/documents/ACT_RR2015-4.pdf

Casillas, A., Way, J. D., Burrus, J., Allen, J. & Hanson, M. A. (2015). Behavioral Skills. In *Beyond Academics: A Holistic Framework for Enhancing Education and Workplace Success* (ACT Research Report Series 2015, vol. 4, pp. 25-38). Retrieved from http://www.act.org/research

Cobern, W. W. (2001). The Thinking About Science survey instrument (TSSI)—An instrument for the quantitative study of socio-cultural sources of support and resistance to science. *Scientific Literacy and Cultural Studies Project* [Paper 37]. Retrieved from http://scholarworks.wmich.edu/science_slcsp/37/

Cooper, R., Loughran, J., & Berry, A. (2015). Science Teachers' PCK. In Berry, A., Friedrichsen, P. & Loughran, J., *Re-examining Pedagogical Content Knowledge in Science Education* (pp. 60-74). New York, NY: Taylor & Francis.

Creswell, J. W. (2012). *Qualitative inquiry and research design: Choosing among five approaches* [Kindle edition]. Thousand Oaks, CA: SAGE Publications.

Cronin-Jones, L. L. (1991). Science teacher beliefs and their influence on curriculum implementation: Two case studies. *Journal of Research in Science Teaching*, *28*(3), 235–250. doi:10.1002/tea.3660280305

Daehler, K. R., Heller, J. I., & Wong, N. (2015). Supporting Growth of Pedagogical Content Knowledge in Science. In Berry, A., Friedrichsen, P. & Loughran, J., *Re-examining Pedagogical Content Knowledge in Science Education* (pp. 45-59). New York, NY: Taylor & Francis.

Dufour, R., Dufour, R., & Eaker, R. (2008). *Revisiting professional learning communities at work* [Kindle edition]. Bloomington, IN: Solution Tree Press. Retrieved from https://www.amazon.com/Revisiting-Professional-Learning-Communities-Work/dp/1934009326#reader_1934009326

Field, A. (2013). *Discovering statistics using IBM SPSS statistics and sex and drugs and rock 'N' roll* (4th ed.) [Kindle Edition]. Sage Publications. Retrieved from http://www.amazon.com

Flavell, J. H. (1976). Metacognitive aspects of problem solving. In L. R. Resnick (Ed.), *The nature of intelligence* (pp. 231–235). Hillsdale, NJ: Lawrence Erbaum.

Gess-Newsome, J. (1999). Pedagogical content knowledge: An introduction and orientation. In J. Gess-Newsome and N. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 3–17). New York, NY: Springer. doi:10.1007/0-306-47217-1_1

Harmston, M. T., Pliska, A. (2001). *Trends in ACT Mathematics and Science Reasoning Achievement, Curricular Choice, and Intent for College Major: 1995-2000*. Retrieved from http://www.act.org

Hashweh, M. Z. (1996). Effects of science teachers' epistemological beliefs in teaching. *Journal of Research in Science Teaching*, *33*(1), 47–63. doi:10.1002/(SICI)1098-2736(199601)33:1<47::AID-TEA3>3.0.CO;2-P

Heller, J. I., Daehler, K. R., Shinohara, M., & Kashowitz, S. R. (2004, April). Fostering pedagogical content knowledge about electric circuits through case-based professional development. In *annual meeting of the National Association for Research in Science Teaching (NARST)*, Vancouver, Canada.

Kesidou, S., & Roseman, J. E. (2002). How well do middle school science programs measure up? Findings from Project 2061's curriculum review. *Journal of Research in Science Teaching*, *39*(6), 522–549.

Kuhn, T. S. (1962). The structure of scientific revolutions. In O. Neurath, R. Carnap, & C. Morris (Eds.), *International encyclopedia of unified science* (2nd ed., Vol. II, No. 2). Retrieved from http://projektintegracija.pravo.hr/_download/repository/Kuhn_Structure_of_Scientific_Revolutions.pdf

Lederman, N. G. (1986). Relating teaching behavior and classroom climate to change in students' conceptions of the nature of science. *Science Education*, *70*(1), 3-19.

Lederman, N. G. (2006). Research on nature of science: Reflections on the past, anticipations of the future. *Asia-Pacific Forum on Science Learning and Teaching, 7*(1), 2. Retrieved from https://www.ied.edu.hk/apfslt/

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39*(6), 497–521.

Lee, E., & Luft, J. A. (2008). Experienced secondary science teachers' representation of pedagogical content knowledge. *International Journal of Science Education*, *30*(10), 1343–1363.

Luft, J. A. (2001). Changing inquiry practices and beliefs: The impact of an inquiry-based professional development programme on beginning and experienced secondary science teachers. *International Journal of Science Education*, *23*(5), 517–534.

Luft, J. A., & Roehrig, G. H. (2007). Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. *Electronic Journal of Science Education*, *11*(2), 38–63.

Luft, J. A., Roehrig, G. H., & Patterson, N. C. (2003). Contrasting landscapes: A comparison of the impact of different induction programs on beginning secondary science teachers' practices, beliefs, and experiences. *Journal of Research in Science Teaching*, *40*(1), 77–97.

Lumpe, A. T., Haney, J. J., & Czerniak, C. M. (2000). Assessing teachers' beliefs about their science teaching context. *Journal of Research in Science Teaching*, *37*(3), 275–292. doi:10.1002/(SICI)1098-2736(200003)37:3<275::AID-TEA4>3.0.CO;2-2

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome and N. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 95–132). New York, NY: Springer.

Marks, R. (1990). Pedagogical content knowledge: From a mathematical case to a modified conception. *Journal of Teacher Education*, *41*(3), 3–11. doi:10.1177/002248719004100302

Mattern, K., & Radunzel, J. (2015). Who goes to graduate school? Tracking 2003 act-tested high school graduates for more than a decade. *ACT Research Report Series, 2015*(2). Retrieved from http://files.eric.ed.gov/fulltext/ED558032.pdf

Mattern, K., Radunzel, J., & Westrick, P. (2015). Development of STEM readiness benchmarks to assist educational and career decision making. *ACT Research Report Series, 2015*(3). Retrieved from https://www.act.org/content/dam/act/unsecured/documents/ACT_RR2015-3.pdf

McNeish, D. M., Radunzel, J., & Sanchez, E. (2015). A multidimensional perspective of college readiness: Relating student and school characteristics to performance on the ACT. *ACT Research Report Series, 2015*(6). Retrieved from http://files.eric.ed.gov/fulltext/ED563774.pdf

National Science Teachers Association. (1982). *Science-technology-society: Science education for the 1980s*. Washington, DC: Author.

Palincsar, A., & Brown, A. L. (1983). *Reciprocal teaching of comprehension monitoring activities* (Center for the Study of Reading Technical Report No. 269). Champaign, IL: University of Illinois/National Institute of Education. Retrieved from https://www.ideals.illinois.edu/bitstream/handle/2142/17612/ctrstreadtechrepv01983i00269_opt.pdf?sequence=1

Piaget, J. (2013). *Success and understanding*. Abingdon-on-Thames, UK: Routledge.

Popham, J. (2011). *Transformative assessment in action* [Kindle edition]. Alexandria, VA: ASCD. Retrieved from https://www.amazon.com/Transformative-Assessment-Action-Applying-Process/dp/141661124X

Riggs, I., & Enochs, L. (1990). Toward the development of an elementary teachers science teaching efficacy belief instrument. *Science Education*, *74*(6), 625–637.

Sampson, V., Grooms, J., & Enderle, P. (2013). Development and initial validation of the Beliefs About Reformed Science Teaching and Learning (BARSTL) Questionnaire. *School Science and Mathematics*, *113*(1), 3–15. doi:10.1111/j.1949-8594.2013.00175.x

Scardamalia, M., Bereiter, C., & Steinbach, R. (1984). Teachability of reflective processes in written composition. *Cognitive Science*, *8*(2), 173–190.

Schoenfeld, A. H. (1991). On mathematics as sense-making: An informal attack on the unfortunate divorce of formal and informal mathematics. In J. F. Voss, D. N. Perkins, & J. W. Segal (Eds.), *Informal reasoning and education* (pp. 311–343). Hillsdale, NJ: Lawrence Erlbaum Associates.

Shulman, L. (2015). PCK: Its genesis and exodus. *Re-examining pedagogical content knowledge in science education*, 3-13.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4–14.

Simmons, P. E., Tillotson, J., Brunkhorst, H., Twiest, M., Hossain, K., Gallagher, J., … Craven, J. (1999). Beginning teachers: Beliefs and classroom actions. *Journal of Research in Science Teaching*, *36*(8), 930–954. doi:10.1002/(SICI)1098-2736(199910)36:8<930::AID-TEA3>3.0.CO;2-N

Skinner, B. F. (1950). Are theories of learning necessary? *Psychological Review*, *57*(4), 193.

Smith, P. S., & Banilower, E. R. (2015). Assessing PCK: A new application of the uncertainty principle. *Re-examining pedagogical content knowledge in science education*, 88-103.

Smith, P. S., Smith, A. A., & Banilower, E. R. (2014). Situating beliefs in the theory of planned behavior: The development of the teacher beliefs about effective science teaching questionnaire. In R. Evans, J. Luft, C. Czerniak, & C. Pea (Eds.), *The role of science teachers' beliefs in international classrooms: From teacher actions to student learning* (pp. 81–102). New York, NY: Springer.

Thorndike, E. L. (1921). *Educational psychology: The psychology of learning* (Vol. 2). New York, NY: Teachers College, Columbia University.

U.S. Department of Education (2006). *The condition of education 2006*. Washington, D.C.: Nation Center for Education Statistics, Institute of Education Sciences. Retrieved from http://nces.ed.gov/pubs2006/2006071.pdf

Van Driel, J. H., Berry, A. (2010. Pedagogical Content Knowledge. In *International Encyclopedia of Education*. (Vol. 7, 656-661). Elsevier.

Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Weiss, I., Pasley, J., Smith, P., Banilower, E., & Heck, D. (2003). *Looking inside the classroom*. Chapel Hill, NC: Horizon Research, Inc.

Wong, S. S., & Luft, J. A. (2015). Secondary science teachers' beliefs and persistence: A longitudinal mixed-methods study. *Journal of Science Teacher Education*, *26*(7), 619–645.

Wormeli, R. (2006). *Fair isn't always equal* [Kindle edition]. Portland, ME: Stenhouse Publishers.

Yerrick, R., Parke, H., & Nugent, J. (1997). Struggling to promote deeply rooted change: The “filtering effect” of teachers’ beliefs on understanding transformational views of teaching science. *Science Education*, *81*(2), 137–159.

APPENDICES

APPENDIX A: TBEST QUESTIONNAIRE

Data—information that has not yet been analyzed or processed; typically gathered through observation or measurement.
Evidence—analyzed or processed data that are used to support a scientific claim or conclusion.

TBEST Questionnaire

Practical constraints aside, do you agree that doing what is described in each statement would help most students learn science?

Circle one in each row.

	Strongly Disagree	Moderately Disagree	Slightly Disagree	Slightly Agree	Moderately agree	Strongly Agree
1. At the beginning of instruction on a science concept, students should be provided with definitions for new scientific vocabulary that will be used.	1	2	3	4	5	6
2. Hands-on activities and/or laboratory activities should be used primarily to reinforce a science concept that the students have already learned.	1	2	3	4	5	6
3. Students should rely on evidence from classroom activities, labs, or observations to form conclusions about the science concept they are studying.	1	2	3	4	5	6
4. Teachers should have students do hands-on activities, even if the data they collect are not closely related to the concept they are studying.	1	2	3	4	5	6
5. Teachers should explain a concept to students before having them consider evidence that relates to the concept.	1	2	3	4	5	6
6. Teachers should provide students with opportunities to connect the science they learn in the classroom to what they experience outside of the classroom.	1	2	3	4	5	6
7. Teachers should ask students to support their conclusions about a science concept with evidence.	1	2	3	4	5	6
8. Students should do hands-on or laboratory activities, even if they do not have opportunities to reflect on what they learned by doing the activities.	1	2	3	4	5	6
9. At the beginning of instruction on a science concept, students should have the opportunity to consider what they already know about the concept.	1	2	3	4	5	6
10. Students should do hands-on activities after they have learned the related science concepts.	1	2	3	4	5	6

Data—information that has not yet been analyzed or processed; typically gathered through observation or measurement.
Evidence—analyzed or processed data that are used to support a scientific claim or conclusion.

Circle one in each row.

	Strongly Disagree	Moderately Disagree	Slightly Disagree	Slightly Agree	Moderately agree	Strongly Agree
11. Teachers should provide students with opportunities to apply the concepts they have learned in new or different contexts.	1	2	3	4	5	6
12. Students should use evidence to evaluate claims about a science concept made by other students.	1	2	3	4	5	6
13. Teachers should have students do interesting hands-on activities, even if the activities do not relate closely to the concept being studied.	1	2	3	4	5	6
14. At the beginning of lessons, teachers should 'hook' students with stories, video clips, demonstrations or other concrete events/activities in order to focus student attention.	1	2	3	4	5	6
15. Students' ideas about a science concept should be deliberately brought to the surface prior to a lesson or unit so that students are aware of their own thinking.	1	2	3	4	5	6
16. Teachers should provide students with the outcome of an activity in advance so students know they are on the right track as they do the activity.	1	2	3	4	5	6
17. Students should have opportunities to connect the concept they are studying to other concepts.	1	2	3	4	5	6
18. Students should consider evidence that relates to the science concept they are studying.	1	2	3	4	5	6
19. When students do a hands-on activity and the data don't come out right, teachers should tell students what they should have found.	1	2	3	4	5	6
20. Students should know what the results of an experiment are supposed to be before they carry it out.	1	2	3	4	5	6
21. Students should consider evidence for the concept they are studying, even if they do not do a hands-on or laboratory activity related to the concept.	1	2	3	4	5	6

APPENDIX B: AVERAGE SCHOOL RESPONSES TO TBEST ITEMS

Science Department Average Response to TBEST items

	School 1		School 2		School 3		School 4	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Item 1	4.55	1.214	4.55	1.440	5.00	1.000	4.38	1.506
Item 2	3.73	1.191	4.27	1.679	5.00	1.265	4.50	1.414
Item 3	5.45	.522	4.91	.539	5.64	.924	5.38	.518
Item 4	3.45	1.508	3.45	1.440	3.36	1.206	3.88	1.553
Item 5	3.36	1.027	3.73	1.348	4.82	1.168	3.38	.744
Item 6	5.91	.302	5.45	.522	5.64	.674	5.88	.354
Item 7	6.00	.000	5.36	.674	5.82	.405	6.00	.000
Item 8	2.64	1.362	2.91	1.446	2.91	1.221	2.38	1.506
Item 9	5.18	.751	5.18	.751	5.45	.934	5.38	.744
Item 10	4.82	1.079	4.45	1.036	5.09	1.136	4.13	1.126
Item 11	5.73	.647	5.27	.467	5.64	.674	5.75	.463
Item 12	5.73	.467	5.00	.632	5.27	.905	5.88	.354
Item 13	2.73	1.009	2.55	1.368	2.91	1.375	2.50	1.414
Item 14	5.18	.751	4.82	.751	4.64	.809	4.88	.641
Item 15	4.91	.831	4.91	.831	4.36	1.362	4.88	.354
Item 16	2.45	1.368	2.00	.894	2.45	1.214	2.00	.535
Item 17	5.64	.505	5.64	.505	5.64	.674	5.75	.463
Item 18	5.45	.688	5.45	.688	5.36	.674	5.75	.463
Item 19	4.18	1.250	3.64	1.206	3.82	1.250	3.63	1.923
Item 20	2.55	1.214	1.82	.982	1.91	.831	2.38	1.685
Item 21	5.64	.505	5.09	1.221	5.18	.603	5.50	.535

Note. For School 1, N = 11; School 2, N = 11; School 3, N = 11; School 4, N = 8.

Items from the TBEST (APPENDIX A: TBEST QUESTIONNAIRE)

Standard Deviation (*SD*)

APPENDIX C: SCHOOL VARIANCES ON TBEST ITEMS

Science Department Variances on TBEST Item Responses

	School 1	School 2	School 3	School 4	Overall
Item 1	1.473	2.073	1.000	2.268	1.588
Item 2	1.418	2.818	1.600	2.000	2.038
Item 3	.273	.291	.855	.268	.480
Item 4	2.273	2.073	1.455	2.411	1.906
Item 5	1.055	1.818	1.364	.554	1.528
Item 6	.091	.273	.455	.125	.262
Item 7	.000	.455	.164	.000	.226
Item 8	1.855	2.091	1.491	2.268	1.801
Item 9	.564	.564	.873	.554	.612
Item 10	1.164	1.073	1.291	1.268	1.230
Item 11	.418	.218	.455	.214	.349
Item 12	.218	.400	.818	.125	.502
Item 13	1.018	1.873	1.891	2.000	1.572
Item 14	.564	.564	.655	.411	.560
Item 15	.691	.691	1.855	.125	.889
Item 16	1.873	.800	1.473	.286	1.139
Item 17	.255	.255	.455	.214	.280
Item 18	.473	.473	.455	.214	.406
Item 19	1.564	1.455	1.564	3.696	1.845
Item 20	1.473	.964	.691	2.839	1.378
Item 21	.255	1.491	.364	.286	.630

Note. For School 1, N = 11; School 2, N = 11; School 3, N = 11; School 4, N = 8.

Items from the TBEST (APPENDIX A: TBEST QUESTIONNAIRE)

Standard Deviation (*SD*)

APPENDIX D: SCHOOL TBEST ANOVA RESULTS

ANOVA Between School TBEST Responses within School District

		Sum of Squares	df	Mean Square	F	Sig.
Item 1	Between Groups	2.183	3	.728	.439	.726
	Within Groups	61.330	37	1.658		
	Total	63.512	40			
Item 2	Between Groups	9.149	3	3.050	1.559	.216
	Within Groups	72.364	37	1.956		
	Total	81.512	40			
Item 3	Between Groups	3.163	3	1.054	2.429	.081
	Within Groups	16.057	37	.434		
	Total	19.220	40			
Item 4	Between Groups	1.369	3	.456	.225	.878
	Within Groups	74.875	37	2.024		
	Total	76.244	40			
Item 5	Between Groups	14.883	3	4.961	3.970	.015
	Within Groups	46.239	37	1.250		
	Total	61.122	40			
Item 6	Between Groups	1.431	3	.477	1.949	.139
	Within Groups	9.057	37	.245		
	Total	10.488	40			
Item 7	Between Groups	2.843	3	.948	5.671	.003
	Within Groups	6.182	37	.167		
	Total	9.024	40			

continued

		Sum of Squares	df	Mean Square	F	Sig.
Item 8	Between Groups	1.810	3	.603	.318	.812
	Within Groups	70.239	37	1.898		
	Total	72.049	40			
Item 9	Between Groups	.613	3	.204	.317	.813
	Within Groups	23.875	37	.645		
	Total	24.488	40			
Item 10	Between Groups	5.072	3	1.691	1.417	.253
	Within Groups	44.148	37	1.193		
	Total	49.220	40			
Item 11	Between Groups	1.542	3	.514	1.533	.222
	Within Groups	12.409	37	.335		
	Total	13.951	40			
Item 12	Between Groups	4.859	3	1.620	3.933	.016
	Within Groups	15.239	37	.412		
	Total	20.098	40			
Item 13	Between Groups	1.060	3	.353	.211	.888
	Within Groups	61.818	37	1.671		
	Total	62.878	40			
Item 14	Between Groups	1.697	3	.566	1.011	.399
	Within Groups	20.693	37	.559		
	Total	22.390	40			

continued

Item 15	Between Groups	2.322	3	.774	.862	.470
	Within Groups	33.239	37	.898		
	Total	35.561	40			
Item 16	Between Groups	2.106	3	.702	.598	.620
	Within Groups	43.455	37	1.174		
	Total	45.561	40			
Item 17	Between Groups	.083	3	.028	.092	.964
	Within Groups	11.136	37	.301		
	Total	11.220	40			
Item 18	Between Groups	.744	3	.248	.592	.624
	Within Groups	15.500	37	.419		
	Total	16.244	40			
Item 19	Between Groups	2.112	3	.704	.363	.780
	Within Groups	71.693	37	1.938		
	Total	73.805	40			
Item 20	Between Groups	3.974	3	1.325	.958	.423
	Within Groups	51.148	37	1.382		
	Total	55.122	40			
Item 21	Between Groups	2.129	3	.710	1.137	.347
	Within Groups	23.091	37	.624		
	Total	25.220	40			

Note. $N = 41$
Items from TBEST questionnaire
Independent variable: schools
Dependent variables: TBEST item

APPENDIX E: IRB EXEMPTION DETERMINATION NOTICE

IRB
INSTITUTIONAL REVIEW BOARD
Office of Research Compliance,
010A Sam Ingram Building,
2269 Middle Tennessee Blvd
Murfreesboro, TN 37129

MIDDLE TENNESSEE STATE UNIVERSITY

IRBN007 – EXEMPTION DETERMINATION NOTICE

Wednesday, June 08, 2016

Investigator(s): Jeff Porter (PI), and Dr. Rick Vanosdall (FA)
Investigator(s') Email(s): jp4z@mtmail.mtsu.edu
Department: ALSI

Study Title: Science Teacher Perspective on Effective Practice and Current ACT Performance
Protocol ID: **16-1277**

Dear Investigator(s),

The above identified research proposal has been reviewed by the MTSU Institutional Review Board (IRB) through the **EXEMPT** review mechanism under 45 CFR 46.101(b)(2) within the research category *(2) Educational Tests* A summary of the IRB action and other particulars in regard to this protocol application is tabulated as shown below:

IRB Action	EXEMPT from furhter IRB review***	
Date of expiration	**NOT APPLICABLE**	
Sample Size	105	
Participant Pool	**High School Science Teachers**	
Mandatory Requirements	Must collect consent forms	
Additional Restrictions	**ONLY TEACHERS IN RUTHERFORD COUNTY SCHOOLS**	
Comments	N/A	
Amendments	**Date**	**Post-Approval Amendments**
	N/A	N/A

***This exemption determination only allows above defined protocol from further IRB review such as continuing review. However, the following post-approval requirements still apply:

- Addition/removal of subject population should not be implemented without IRB approval
- Change in investigators must be notified and approved
- Modifications to procedures must be clearly articulated in an addendum request and the proposed changes must not be incorporated without an approval
- Be advised that the proposed change must comply within the requirements for exemption
- Changes to the research location must be approved – appropriate permission letter(s) from external institutions must accompany the addendum request form
- Changes to funding source must be notified via email (irb_submissions@mtsu.edu)
- The exemption does not expire as long as the protocol is in good standing
- Project completion must be reported via email (irb_submissions@mtsu.edu)

IRBN007 Version 1.2 Revision Date 03.08.2016

- Research-related injuries to the participants and other events must be reported within 48 hours of such events to compliance@mtsu.edu

The current MTSU IRB policies allow the investigators to make the following types of changes to this protocol without the need to report to the Office of Compliance, as long as the proposed changes do not result in the cancellation of the protocols eligibility for exemption:

- Editorial and minor administrative revisions to the consent form or other study documents
- Increasing/decreasing the participant size

The investigator(s) indicated in this notification should read and abide by all applicable post-approval conditions imposed with this approval. Refer to the post-approval guidelines posted in the MTSU IRB's website. Any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918 within 48 hours of the incident.

All of the research-related records, which include signed consent forms, current & past investigator information, training certificates, survey instruments and other documents related to the study, must be retained by the PI or the faculty advisor (if the PI is a student) at the sacure location mentioned in the protocol application. The data storage must be maintained for at least three (3) years after study completion. Subsequently, the researcher may destroy the data in a manner that maintains confidentiality and anonymity. IRB reserves the right to modify, change or cancel the terms of this letter without prior notice. Be advised that IRB also reserves the right to inspect or audit your records if needed.

Sincerely,

Institutional Review Board
Middle Tennessee State University

Quick Links:

Click here for a detailed list of the post-approval responsibilities.
More information on exmpt procedures can be found here.