RELATIONSHIP BETWEEN REFORMED SCIENCE TEACHING AND LEARNING BELIEFS AND CLASSROOM PRACTICE: A TWO-PART STUDY

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Abstract: Research examining the relationship between teachers' beliefs and classroom practice has been on the rise. While several researchers (Buehl & Beck, 2015; Fang, 1996; Pajares, 1992) have examined the relationship between teachers' beliefs and practice, there is not one agreed upon conclusion. This dissertation, presented as two studies, seeks to explore the relationship between secondary science teachers' beliefs and their self-reported classroom practice. The first study extends the application and use of the Beliefs About Reformed Science Teaching and Learning (BARSTL) (Sampson, Enderle, & Grooms, 2013) instrument as a way to (a) determine what secondary science teachers believe and (b) apply Grid and Group theory (Douglas, 1970, 1973, 1982; Harris, 2006) as a way to categorize teachers based on their beliefs. The second qualitative study utilizes the Grid and Group cultural map (Douglas, 1970, 1973, 1982; Harris, 2006) proposed in study one to create multiple-case studies to investigate teachers' classroom practice, as reported through interviews and lesson planning documents, based on their beliefs about the teaching and learning of science (Sampson et al., 2013). Overall results indicate a statistical difference teachers' beliefs and their education level and the number of undergraduate science courses taken. The Grid and Group typology allowed for visual representation of differences among the sample and the purposeful selection of participants for the case studies. The resulting multiple case studies found: (a) a cross-case belief regarding a focus on teaching the essentials, (b) consistency between traditional beliefs and practice but inconsistencies between reformed beliefs and practice, and c) support for the creation of a transitional zone on the cultural map similar to previous studies (Luft & Roehrig, 2007). Case studies illustrate change as a process that proceeds through transition, and at times conflict, between beliefs and practice. Findings support the inconsistency perspective between beliefs and classroom practice and illustrate the complex relationship between the two constructs. Classroom practice was self-reported, thus limiting the generalizability to other contexts and further research is needed utilizing direct observation.

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CHAPTER I

INTRODUCTION

Teachers' beliefs and practice have been, and continue to be, a major focus in educational research. Many research studies have focused on the complexity of teacher beliefs, classroom practice, and the relationship between the two (e.g. Bryan, 2012; Calderhead, 1996; Capps, Shemwell, & Young, 2016; Cronin-Jones, 1991; Haney, Czerniak, & Lumpe, 1996; Hutner & Markman, 2017; King, Shumow, & Lietz, 2001; Luft, 1999; Roehrig & Kruse, 2005; Veal, Riley Lloyd, Howell, & Peters, 2016; Verjovsky & Waldegg, 2005; Wallace, 2014). Though the research on these variables is extensive (see Bryan, 2012 and Wallace, 2014), findings are not conclusive; rather, they are in conflict. Research into teacher beliefs, classroom practice, and the relationship between these constructs has been a focus of science education reform (Bryan, 2012; Wallace, 2014). With the publication of the *National Science Education Standards* (National Research Council, 1996), *The Framework for K-12 Science Education* (National Research Council, 2012), and *The Next Generation Science Standards* (NGSS Lead States, 2013), researchers have offered insights into why continued science education reform persists in the education system as educators work to fully implement and actualize the needed reform. The research literature provides reasons why full implementation and actualization has not occurred and the need for continued reforms: accessibility for traditionally underserved populations (Lee, Miller, & Januszyk, 2014), lack of proper teacher preparation and professional development (National Research Council, 2012), increased high stakes testing (Whitford & Jones, 2000), and incongruence of teacher beliefs and practice (Bartos & Lederman, 2014; Cronin-Jones, 1991; Sampson et al., 2013).

Munby (1984) stated that “part of a teacher’s context which is evidently significant to adopting research findings or implementing curricula is what a teacher believes” (p. 28). Taking this thought a step further, Cronin-Jones (1991) suggested that the success of the current science education reform movement depends in part on the integration of reform-based beliefs and in-service teacher practice, because beliefs act as a filter through which classroom practices are enacted (Crawford, 2007; Sampson et al., 2013). This study will explore teachers’ beliefs utilizing a modern understanding of reformed science education beliefs (Sampson et al., 2013) and self-reported classroom practices through a cultural and context-based lens (Douglas, 1970, 1973, 1982). The use of self-reported classroom practice over the ideal classroom observations was due to limits placed by the school district within the study. This research focuses on the relationship of these variables, teacher beliefs and self-reported classroom practice, and the possible effects each has on the other. Due to the continued focus on science educational reform, the need to reconsider the role of the teacher in science educational reform efforts and the idea that teachers’ beliefs influence classroom practice, this study will add to the existing literature by addressing the relationship between both teachers' beliefs about the teaching and learning of science and their self-reported classroom practice.

Statement of the Problem

Buehl and Beck (2015) identified four major, but conflicting, perspectives of the relationship between beliefs and practices: 1) beliefs influence practice, 2) practice influences beliefs, 3) beliefs are disconnected to practice, and 4) beliefs and practice represent a complex reciprocal relationship. Further convoluting the relationship, teaching practice is situated within the culture of the school and constrained by curriculum and policy requirements (Brickhouse, 1990; Brickhouse & Bodner, 1992; Keys, 2005; Lederman, 1992). Bryan (2012) asserted that within the existing literature on the relationship between teachers' beliefs and classroom practices, two conflicting perspectives are presented: congruity and incongruity.

When beliefs and practice are in congruence, teachers stated beliefs, whether more traditional or reformed, match what is occurring in classroom. For example, teachers who supported reformed perspectives regarding the teaching and learning of science worked enthusiastically, implemented lessons more consistent with reform efforts at their schools (Levitt, 2002), and developed innovative formative assessment strategies that promoted the implementation of required reform (Wallace & Priestley, 2011a). Buehl and Beck (2015) further supported the congruity perspective by stating that teachers "who express more traditional views of teaching consistently implemented traditional lessons" (p. 73). On the other hand, incongruence between beliefs and practice represents a mismatch between what a teacher believes and what occurs in the classroom. Cronin-Jones (1991) and Yerrick, Parke, and Nugent (1997) found that teachers who held strong beliefs towards implementing constructivist-based curriculum either converted or continued to teach curriculum which matched a more traditional perspective representing incongruence. It is clear that both congruity and incongruity perspectives are present, but unresolved, in previous literature, supporting the need for additional research into teachers' beliefs, teachers' classroom practices, and the relationship between the two (Bryan, 2012; Buehl & Beck, 2015; Fang, 1996).

Purpose of the Study

The purpose of this study is twofold. First, a quantitative investigation of teachers' beliefs about the teaching and learning of science, using the Beliefs about Reformed Science Teaching and Learning (BARSTL) questionnaire (Sampson et al., 2013), allows for the exploration of existing beliefs that secondary science teachers hold. Through the application of Grid and Group Theory (Douglas, 1970, 1973, 1982; Harris, 1995, 2005) on teachers' beliefs, a cultural typology was developed to categorize teachers into groups based on either traditional or reformed perspectives. In addition, demographic data will be used to investigate larger population characteristics.

Second, this study will qualitatively explore secondary science teachers' self-reported classroom practices bounded by teachers' beliefs about the teaching and learning of science. Doing so will allow for a rich, descriptive look into classroom practice in order to develop a cross-case comparison. Overall, the purpose of this study is to identify secondary teachers' beliefs about the teaching and learning of science and explore the classroom practices associated with these beliefs.

Research Questions

This dissertation is divided into two studies: the first quantitative, the second qualitative. The following research questions guide the quantitative study:

- What are in-service secondary science teachers' beliefs about the teaching and learning of science?
    - Is there a significant difference in the Beliefs about Reformed Science Teaching and Learning (BARSTL) scores and teachers' demographics (i.e., gender, race, highest education level, and current grade taught)?
    - Does years of teaching experience predict BARSTL scores?
- What is the resulting Grid and Group cultural map when using teachers' beliefs as measured by the BARSTL?
    - Does the Grid and Group cultural map show demographics differences between teacher beliefs as measured by the BARSTL?
    - How do the dimension of Grid and Group explain teachers' beliefs about reformed science teaching and learning as measured by the BARSTL?

The following research questions guide the qualitative study:

- What are secondary science teachers' beliefs and self-reported classroom practices?
- How do secondary science teachers' beliefs influence their self-reported classroom practices?

Significance of the Study

Previous research using the BASRTL focused on (a) investigating the change in beliefs through various professional development opportunities (Golden et al., 2008; Granger, Bevis, Saka, Fakultesi, & Southerland, 2010; Granger, Bevis, Saka, & Southerland, 2009); (b) overcoming barriers of reform through situated instructional coaching (Czajka, 2014); (c) determining beliefs of prospective and first-year elementary teachers (Karaman & Karaman, 2013); (d) determining teacher practice based on beliefs (Büyüktaskapu, 2010); (e) determining the relationship between principals' views of science teaching and learning and student outcomes (Khan, 2012); and (f) explaining the variation of self-reported teaching practice and beliefs (Jetty, 2014). Each of these studies followed the assumption made by Sampson et al. (2013), that the beliefs teachers hold influence their resulting enacted classroom practice. This assumption takes the perspective that there is congruence between teachers' beliefs and classroom practice. Skott (2015) and Buehl and Beck (2015) discussed conflicting findings within the literature regarding the relationship between teachers' beliefs and classroom practice. Fives and Buehl (2012) suggested that there are equal numbers of studies supporting a theory of congruence as there is of incongruence, as such what a teacher reports as their classroom practice does not necessarily match their actual classroom practice (Bryan, 2012). Specifically, Capps and Crawford (2013) found that when selecting their best inquiry lesson, teachers did not actually select inquiry lessons. Therefore, the goal of this study is to further investigate the beliefs secondary science teachers hold and their current classroom practices. By doing so, this study will add to the existing research on the relationship between teachers' beliefs and classroom practice. Additionally, this study will address the missing connection between the constructs of the BARSTL and self-reported classroom practice in hopes to further the use and application of the instrument. This study will also explore both how the BARSTL can be used to look at classroom practice and if the beliefs teachers hold are related to self-reported classroom practice. Lastly, the findings of this study will inform the development and revision of professional development for in-service teachers with the intention of improving classroom practice.

The context and nature of this study has a set of limitations, delimitations, and assumptions. The study only looked at one district, and one small sample of secondary science teachers and thus should not be generalized to the larger population of secondary science teachers. The data gathered, both quantitative and qualitative, represents self-reported data and should be taken as such. The findings presented do not represent actual observations of classroom practice due to factors outside the control of the researcher. The delimitations of this research are that this study does not seek to correlate the belief statements on the BARSTL with that of The Framework for K-12 Science Education or NGS. Additionally, the findings relating to classroom practice do not apply judgement as to what type of classroom practice leads to increases or decreases in other variables, rather it presents what was found as it is. The researcher assumes that the participants in the study honestly responded to the questionnaire and interview questions. The researcher also assumes that the experiences that teachers have within the district are similar, thus supporting the development of multiple cases studies designed to explore differences in self-reported classroom practice as defined by their beliefs.

Preview of Remaining Chapters

This dissertation is formatted in a two-study format with a traditional literature review and conclusion chapter. The literature review focused on teacher beliefs, classroom practice, and the relationship between these two variables. Bringing the previous constructs together, a discussion relating the use of the Beliefs About Reformed Science Teaching and Learning questionnaire and construct (Sampson et al., 2013) is presented as the overarching framework for this study. Chapter 3 presents a quantitative study into teachers' beliefs at a large Midwestern school district. Chapter 4 presents a qualitative study looking at teachers' self-reported classroom practice that utilizes the findings from the study in chapter 3. The final chapter presents a synthesis of findings from both studies and connects the entire dissertation to the body of research into the relationship between teacher beliefs and classroom practice.

CHAPTER II

REVIEW OF LITERATURE

To provide context to the focus and purpose of this study, a review of literature around teachers' beliefs, classroom practice, and the relationship between the two variables will center this study within the field. Understanding both constructs independently will allow for a discussion of existing research regarding the relationships existing between and among the two constructs.

Teacher Beliefs

The construct and definition of teacher beliefs has not been consistently used throughout the literature (Bryan, 2012). Beliefs compose a group of psychological constructs which "describe the structure and content of human thought" (Bryan, 2012, p. 487) that has an assumed relationship with a person's actions (Ajzen, 1985, 1991, 2012). The following fundamental assumptions were summarized and identified by Bryan (2012) in a review of 25 years of science education research:

- Beliefs do not exist in complete independence of one another, but are structured into an 'internal architecture' of systems that are psychologically, but not necessarily logically organized.
- Not all beliefs are of equal importance to the individual. They are prioritized according to their relationship to other beliefs or other cognitive and affective structure.
- Beliefs are held along a continuum of centrality – some are more central, core, or primary, than others. It follows that the more central a belief is, the more resistant to change that belief will be.
- When a belief is changed, the centrality of that belief has repercussions for the entire belief system.
- Beliefs are far more influential than knowledge in discerning how individuals frame and organize tasks and problems and are stronger predictors of behavior (p. 478-479).

In a related but independent review of 300 published articles, Fives and Buehl (2012) found the following characteristics to be predominant in how researchers defined teacher beliefs:

- Teachers' beliefs are implicit, unaware but guiding behavior and filtering practice, and explicit, conscious with the ability to communicate and share;
- Beliefs exist along a continuum of stability from stable and unchanging to dynamic and responsive to intervention;
- Teachers' beliefs are activated by context demands and can be viewed as context-dependent (Verjovsky & Waldegg, 2005), context-independent (Hermans, van Braak, & Van Keer, 2008), or both (Buehl & Fives, 2009);
- Teachers' knowledge and beliefs are interwoven and at times hard to disentangle and become blurred; and

- Beliefs are best understood as integrated systems that take into account physical and social reality (Rokeach, 1968).

Considering the previously mentioned studies which discussed belief characteristics, while done independently, both have similar features: teacher beliefs are conceptualized on a continuum, dynamic over time and experience, and complex in nature and connectedness. While these features represent how teacher beliefs are characterized within the literature, two major research agendas have emerged. Kagan (1992) identified two main research agendas in the research on teachers' beliefs: teachers' sense of self-efficacy and content-specific beliefs. Teaching self-efficacy refers to the beliefs regarding teachers' ability to influence students and their ability to perform certain professional tasks (Bandura, 1977). Content-specific beliefs focus on a teacher's "orientation to specific academic content [and includes] his or her judgements about appropriate instructional activities, goals, forms of evaluation, and the nature of student learning" (Kagan, 1992, p. 67). More recently, Fives and Buehl (2012) concluded that beliefs can be categorized to include beliefs about the "(a) self, (b) context or environment, (c) content or knowledge, (d) specific teaching practices, (e) teaching approaches, and (f) students" (p. 472). The focus of this review is on content-specific beliefs, including beliefs about specific teaching practices and approaches, regarding the teaching and learning of science. Several researchers have proposed belief structures and functions: nested beliefs (Bryan, 2003; Tsai, 2002), core and peripheral beliefs structures (Haney & McArthur, 2002), and beliefs as filters (Savasci & Berlin, 2012; Yerrick et al., 1997). The next section discusses these belief structures and functions in detail.

Belief Structures and Functions

In a case study of one prospective elementary school science teacher, Bryan (2003) described the teachers' beliefs as being nested, sets of beliefs connected and integrated into one tightly held system. Bryan (2003) provided an analogy that described the interwoven nestedness of beliefs as being "much like the twigs that comprise a bird's nest" (p. 840). The study found that the teacher held two belief nests that represented the core of what she believed and effected justification for interactions, planning, and classroom practice. These two belief nests were described as either (a) foundational beliefs, a set of beliefs established as the core beliefs about science teaching and learning, or (b) dualistic beliefs, sets of beliefs that are in contradiction. Tsai (2002) also described the nestedness of 37 science teacher beliefs and found that the majority of experienced teachers held similar views about the teaching and learning of science and the nature of science. This aligned belief system between the teaching, learning, and nature of science was described as being nested whereas the two teachers in Tsai's (2002) study who held beliefs in contradiction were described as being divergent.

Related to the idea of nestedness of beliefs, Haney and McArthur (2002) provided a second perspective of beliefs and described beliefs as being within a system influencing classroom practice either as core or peripheral. Beliefs that were enacted in the classroom and espoused by the teacher were referred to as being core beliefs, whereas peripheral beliefs were not enacted in the classroom but were influenced by the environment the teacher worked within (Haney & McArthur, 2002). Haney and McArthur (2002) utilized the analogy provided by Rokeach (1968) where the belief system is similar to an atom, in that central beliefs are important and resistant to change and hold the peripheral, less important but still influential, beliefs together.

A third related function of beliefs is viewing beliefs as a filter in which incoming information and learning, professional development or experience, is filtered to determine relevance, importance, and response (Fives & Buehl, 2012; Nisbett & Ross, 1980; Savasci & Berlin, 2012; Yerrick et al., 1997). Looking at the beliefs held by eight middle school science teachers, Yerrick et al. (1997) found that their beliefs were static and unchanging. Additionally, as new information was presented, the teachers filtered this information to determine what they believed was important and relevant to their practice (Yerrick et al., 1997). Savasco and Berlin (2012) described the effect teacher education, prior experiences, background, pedagogical content knowledge, and view of the nature of science beliefs had on their filter regarding classroom practice. Teachers filter these beliefs through aspects of their context (e.g. school resources, standardized testing, parental involvement, student ability and behavior, and standards) to ultimately guide their classroom practice (Savasci & Berlin, 2012).

Beliefs are measured in a variety of different methods: surveys/questionnaires, observations protocols, and interview protocols (Heath, Lakshmanan, Perlmutter, & Davis, 2010). There are several existing instruments that ask teachers to evaluate a belief statement or open-ended question based on their own belief structures (e.g. Teacher Beliefs about Effective Science Teaching (Smith, Smith, & Banilower, 2014), Beliefs About Reformed Science Teaching and Learning (Sampson et al., 2013), Views of Nature of Science questionnaire (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002)). Similar to these types of belief instruments, interview protocols, such as the Teacher Belief Instrument (interview protocol)

(Luft & Roehrig, 2007), gather teachers beliefs through an interview protocol. Lastly, teacher beliefs can be inferred through direct observation of their teaching as used with the Reformed Teacher Observation Protocol (Sawada et al., 2002). While there are many different methods to gather teacher beliefs, Heath et al. (2010) concluded that there is not one best way; rather, the instrument must match the purpose of the study. Additionally, the importance of measuring and changing teachers' beliefs can be linked to increases in student outcomes (e.g., Muijs & Reynolds, 2002), change in instructional practices (e.g., Abrami, Poulsen, & Chambers, 2004), and successful implementation of curriculum (e.g., Cronin-Jones, 1991). While the implications of the relationship between teachers' beliefs and other constructs besides self-reported classroom practice is important, this study only seeks to explore how beliefs and self-reported practice are related.

The construct of teacher beliefs has been used throughout the literature extensively, but inconsistently. Two major approaches to research of teacher beliefs include teaching self-efficacy and content-specific beliefs. This research focuses on content-specific beliefs relating to the teaching and learning of science. The research has shown that teachers' beliefs can be viewed as nested beliefs (Bryan, 2003; Tsai, 2002), core and peripheral beliefs structures (Haney & McArthur, 2002), or beliefs as filters (Savasci & Berlin, 2012; Yerrick et al., 1997). This research contributes to our understanding of teacher beliefs by utilizing the construct of "reformed beliefs about science education" (Sampson et al., 2013, p. 6). Within our understanding of teachers' beliefs, there is an underlying assumption about what constitutes reformed science teaching and learning. The following section presents a historical view of the development of current reformed science teaching and learning.

Science Teaching and Learning

Educational reform has been, and continues to be, a major focus in educational research. Our understanding of effective science teaching and learning is extensive, complex, and messy (Lucero, Valcke, & Schellens, 2013). This section presents literature related to science educational reform in relation to both previous and current understandings of effective science teaching. Despite sustained efforts in science education reform, Haney, Czerniak, and Lumpe (1996) asserted that "the United States is amidst a large-scale science education reform movement" (p. 971). Woodbury and Gess-Newsome (2002) claimed that attending school is "fundamentally the same as it was 100 years ago" (p.764). Despite the struggles to enact reform, Kahle (2007) stated that through previous reform processes, two lessons have been learned: 1) "large-scale reform of science education takes time" and 2) "systemic reforms must include both top-down and bottom-up approaches" (p. 934). The National Research Council (2012) published *A Framework for K-12 Science Education* highlighting, again, the need for continued reform regarding how science is taught in order to promote student learning and achievement in response to the continued problematic issues of reform efforts.

A Brief History of Reform

The progressive educational reform movement that brought science to the forefront of public education began with the Committee of Ten which met in 1892 (Bohan, 2003; DeBoer, 1991). The Committee of Ten determined that science would make up 25% of the high school curriculum, establishing science as a unique and significant part of the curriculum and public education, and that all students should receive an education for the preparation of life rather than solely for college (Bohan, 2003; DeBoer, 1991). Another major reform occurred with the publication of *A Nation at Risk*, which highlighted the inadequacies of American science education among other subjects (National Commission on Excellence in Education, 1983). As a result of the negative public perception and call for reform, science education underwent another major reform outlined in the publication of *Science for All Americans* (American Association for the Advancement of Science, 1990). The next decades saw more publications that encouraged the continued growth and support of science education reform including *The Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993), the *National Science Education Standards* (NSES) (National Research Council, 1996), the *Framework for K-12 Science Education* (National Research Council, 2012), and *Next Generation Science Standards* (NGSS) (NGSS Lead States, 2013), which all continued to build on the idea of enhancing science education within America. Each promotes a way of teaching and learning science that is consistent with our current understanding of how students best learn science. Throughout the foundation documents, many different terms (e.g. constructivism, inquiry, research, investigation, guided discovery, and scientific practices) are presented, each adding to our understanding of the reform-based science teaching and learning construct (Lucero et al., 2013; Sampson et al., 2013). However, even after over 100 years of science education reform, little reform has taken place (Haney et al., 1996; Woodbury & Gess-Newsome, 2002). The following section describes the development of our current understanding of effective science teaching and learning starting from a historical perspective.

Approaches to Science Teaching and Learning

Based on the foundational work by John Dewey (1916) and Jean Piaget (1936), constructivism refers to a philosophical understanding of how effective learning occurs within classrooms. A constructivist view of education indicates that "knowledge is not transmitted directly from one knower to another, but is actively built up by the learner" (Driver, Asoko, Leach, Scott, & Mortimer, 1994, p. 5). It can also be described as an individual's interactions with peers and the contextual environment during the construction or revision of knowledge (Tseng, Tuan, & Chin, 2013). From the constructivist view, learners construct their own knowledge through the process of taking in new and/or competing information, make sense of this new information, and then revise their own understandings to fit the new input (National Research Council, 2000a).

Science teachers who use constructivist principles are student-centered rather than teacher-centered. Von Glasersfeld (1989) described a student-centered classroom as teacher-facilitated where students learn through group learning in which students discuss various approaches to a given problem or situation. Additionally, a student-centered classroom makes learning become an active, social process that requires students to make sense of experiences and "is something students do, not something that is done to them" (National Research Council, 1996, p. 22). Teachers coming from a constructivist approach facilitate learning opportunities that allow students to access existing knowledge and misconceptions in order to build upon their understandings. Constructivism supports the understanding that science teaching and learning should occur through a minds-on activity were students are actively engaged in the construction of scientific knowledge (National Research Council, 1996).

Developing out of the understanding of constructivism, the idea of inquiry-based instruction became explicit with the release of the Benchmarks of Science Literacy (American Association for the Advancement of Science, 1993) and the NSES (National Research Council, 1996). The NSES recognizes a dichotomy between two different ideas of what inquiry is: (a) "the diverse ways in which scientists study the natural world and propose explanation based on the evidence derived from their work" and (b) "the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (National Research Council, 1996, p. 27). Inquiry-based instruction establishes a classroom where students are engaged in open-ended and student-centered activities. Students in an inquiry-based environment are allowed to explore a topic while learning how science is conducted (Smolleck, Zembal-Saul, & Yoder, 2006). Teachers in this environment act as facilitators, whereas students are self-directed and are encouraged to direct the learning (Anderson, 2002). Moreover, the teacher "models the skills of scientific inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterize science" (National Research Council, 2000b, p. 22). While an inquiry-based approach to science teaching and learning allowed students to engage in the practice of science, the practice of science became disconnected and isolated from the content standards. The disconnect occurred between the knowledge gained from science and the scientific practices that allowed the knowledge to be known. This disconnection led to a focus on isolated facts rather than knowledge developed out of the integration of both the practice and knowledge of science (National Research Council, 2012).

In response to this need, The Committee on a Conceptual Framework for New K-12 Science Education Standards was charged by the National Research Council to develop a conceptual framework for creating new science standards (National Research Council, 2012). The resulting document, *A Framework for K-12 Science Education* (National Research Council, 2012), builds on the *Benchmarks for Science Literacy* (American Association for the

Advancement of Science, 1993) and the *National Science Education Standards* (National Research Council, 1996). Central principles to the framework include "young children's capacity to learn science, a focus on core ideas, the development of true understanding over time, the consideration both of knowledge and practice, the linkage of science education to students' interests and experiences, and the promotion of equity" (National Research Council, 2012, p. 24). The development of the NGSS centered around three pillars which support the teaching and learning of science: 1) science and engineering practices, 2) cross-cutting concepts, and 3) disciplinary core ideas, (NGSS Lead States, 2013). These new standards are being implemented in school systems across the nation and are vitally important to the success of the latest reform effort (Osborne, 2014).

While the history of science education reform is extensive, it is important to understand both the context in which it has developed and the trajectory in which it is headed. This research specifically addresses the need to look at the difference between traditional and reformed teacher beliefs and practice. During the implementation of the new standards it is vital that the beliefs teachers hold about the teaching and learning of science are taken into consideration, as we know that there exists a relationship, complex and messy, between the two constructs of beliefs and practice (Bryan, 2012; Fives & Buehl, 2012).

Relationship between Beliefs and Practice

The research on teachers' beliefs is extensive, extending well beyond the last 60 years, but not conclusive (e.g., Bryan, 2012; Fives & Buehl, 2012; Pajares, 1992; Savasci & Berlin, 2012). Additionally, the influence that teachers' beliefs have on the teaching and learning of science is established, but the exact nature of the relationship is still debated (e.g., Bryan, 2012; Cotton, 2006; Cronin-Jones, 1991; Driel, Bulte, & Verloop, 2005; Olson, 1981; Wallace, 2014; Wallace & Kang, 2004; Wallace & Priestley, 2011a; Yerrick et al., 1997). With new reform initiatives emerging in science education calling for major shifts and innovations in the way science is taught, research into the relationship between teachers' beliefs and practices is paramount (Bryan, 2012). Research exploring the effect that teachers' beliefs have on classroom practices has indicated either consistency (congruence) or inconsistency (incongruence) between the beliefs and practice which are influenced by contextual factors (Bryan, 2012; Fives & Buehl, 2012). Studies supporting either side provided justifications including teaching context (Hodson, 1993; Jackson, 2011), occupational culture (Schempp, Sparkes, & Templin, 1993), and existing strongly held beliefs (Waters-Adams, 2006). Two clarifications should be noted: 1) beliefs can be determined either by self-reported claims, espoused beliefs, or inferred from teacher practice (Bryan, 2012) and 2) a difference exists between beliefs "based on evaluation and judgement" and knowledge based on "objective fact" (Pajares, 1992, p. 313). With the increase in studies investigating the relationship between beliefs and practices, Bryan (2012) concluded that the major assertions within the literature lean toward incongruity between beliefs and practice. The following sections present the two different perspectives, consistency and inconsistency, within the current research into the teaching and learning of science.

Consistency Perspective

The consistency perspective supports the assertion that the beliefs teachers' hold match their classroom practice. Kagan (1992) found in a review of empirical studies that teachers' beliefs and their resulting classroom practice were in congruence with each other. The relationship is especially evident when teachers hold traditional beliefs about science relating to a teacher-centered approach focusing on the transmission of knowledge (Bryan, 2012; Calderhead, 1996; Hashweh, 1996). Jones and Carter (2007) found that the beliefs teachers held did have a significant role in shaping classroom practice, even when the relationship was not "linear or obvious" (p. 1067). In an extensive case study of a female teacher, Bryan (2003) found that her belief profile supported the assertion that "beliefs drive practice" (p. 857). In the case study, Bryan (2003) described the teacher's beliefs as being an interwoven set of beliefs, which formed competing nests of beliefs. Bryan (2003) observed that the teacher would switch between the two nests while she was teaching to justify her practice. In a quantitative study, Haney, Czerniak, and Lumpe (1996) used the theory of planned behavior (Ajzen, 1985, 1991, 2012) to look at the relationship between beliefs and practice. Prediction of classroom practice from the beliefs that the teachers held supported the consistency perspective.

Within the consistency perspective, the belief a teacher holds matches that of their practice. When dealing with change, how either their beliefs or practice changes is related to the type of experience and target change in pedagogy (Fives & Buehl, 2012). In an in-depth case study of a teacher in Mexico, Verjovsky and Waldegg (2005) found that her traditional beliefs about teaching matched that of her classroom practice. When the teacher was presented with new and innovated teaching approaches, difficulties integrating these new approaches were observed. On the other hand, Luft (1999) found that there was consistency between implicit beliefs and classroom practice and that the two constructs interacted. As teachers became more aware of their own beliefs, they become more likely to implement change in their practice. Roehrig and Kruse (2005) found that teachers' classroom practice became more aligned with a reformed perspective of science teaching and learning the more they used the new standards and curriculum. The researchers attributed the change in teachers' practices to their change in belief (Roehrig & Kruse, 2005). While these studies illustrated the consistent perspective between beliefs and practice and illustrate differences between findings, others found inconsistencies between beliefs and practice.

Inconsistency Perspective

Inconsistency between beliefs and practice demonstrates that the relationship between espoused beliefs does not necessarily directly influence teachers' practice in the classroom (Bryan, 2012; Dolphin & Tillotson, 2015). Kang and Wallace (2005) found that teachers who held traditional beliefs of teaching demonstrated this in the classroom through a show-and-tell approach, but found that teachers with more reformed views of teaching did not show as straightforward connection between their beliefs and classroom practice. The inconsistency between more reformed beliefs might be seen because of the relationship between beliefs, teaching context, and instructional goals (Wallace & Kang, 2005). Others have found similar findings (e.g. Hodson, 1993; Savasci and Berlin, 2012; and Wallace, 2005). Teachers who embraced constructivism within their beliefs did not show this in their classroom behaviors (Savasci & Berlin, 2012). Despite the variety of findings within the research relating teachers beliefs and practice, it is important to investigate the degree to which the two align and the impacts context has on the negotiation between the two (Fives & Buehl, 2012).

Two case studies of middle school science teachers demonstrate the relationship between the beliefs held and their classroom practice. Trumbell, Scarano, and Bonney (2006) found that the teachers stated that they supported a reformed perspective regarding science instruction through the use of nature of science tenants, but neither of these teachers enacted their beliefs in the classroom. Cronin-Jones (1991) looked at the implementation of a “discovery-oriented constructivist model” (Cronin-Jones, 1991, p. 238) curriculum package to investigate how the teachers’ beliefs influenced their ability to use the curriculum as intended. The teachers’ beliefs were inconsistent with the curriculum and were effected by beliefs regarding how students learn, the role of the teacher, middle school student abilities, and importance of content topics. In both of these studies, the teachers expressed that they tried to implement the intended curriculum, but their beliefs about factual knowledge gained through drill and practice and negative view of students’ ability to be self-directed created an inconsistency between beliefs and practice.

In an effort to approach the research into the relationship between beliefs and practice, Hutner and Markman (2017) concluded that current research supports the idea that teachers quickly disregard their pedagogical learning from teacher education programs to adopt more traditional approaches, and that self-reported beliefs did not match what was observed in the classroom. Through a proposed model, the disparity between beliefs and practices could be attributed to the goals teachers hold (Hutner & Markman, 2017). That is, if a teacher has a goal for increased test scores and has had success in a traditional approach they are likely to keep the perceived success. Capps, Shemwell, and Young (2016) found that the rate at which teachers reported to enact inquiry (reformed practices) was significantly higher than their actual knowledge of inquiry within the classroom. King, Shumow, and Lietz (2001) also observed a disconnect between what a teacher said they were doing in the classroom and what was actually occurring. Beliefs alone were found to not be a good indicator of reformed-based science and teaching, rather Veal et al. (2016) found that the claims they made about their teaching was a better predictor of classroom practice.

The relationship between beliefs and practice is complex and not conclusive. While the majority of the studies support the understanding of inconsistencies between beliefs and practice (Bryan, 2012), it is important to understand what teachers believe within the context of their classroom practice due to the complexities that exist between traditional and reformed science teaching and learning (Bryan, 2012; Calderhead, 1996; Fives & Buehl, 2012; Hashweh, 1996). This present study contributes to the understanding of the relationship between teachers' beliefs and classroom practices by adopting an approach that frames classroom practices by both context and nature of their beliefs.

Beliefs about Science Teaching and Learning

Teachers hold beliefs about the teaching and learning of science that follow a set of assumptions about the nature of these beliefs discussed earlier within the review of literature (Bryan, 2012; Fives & Buehl, 2012) and are either consistent or inconsistent with their classroom practice. In an effort to integrate what is known about reformed-based science teaching and learning and the relationship between beliefs and practice, this study utilized Sampson, Enderle, and Grooms' (2013) construct of "reformed beliefs about science education" (Sampson et al., 2013, p. 6). This construct is defined as the "degree to which science teachers' beliefs about the teaching and learning of science are aligned with the current reform movement in science education" (Sampson et al., 2013, p. 5). This construct is measured by the Beliefs About Reformed Science Teaching and Learning (BARSTL) questionnaire (Sampson et al., 2013) that divides the construct into four subscales: (1) how people learn about science; (2) lesson design and implementation; (3) characteristics of teachers and the learning environment; and (4) the nature of the science curriculum. Each subscale differentiates reformed and traditional perspectives within the overarching construct (see Table 2.1). Sampson, Enderle, and Grooms (2013) described a reformed perspective consistent with the following principles: (a) ideas students bring into the classroom influence learning, (b) learning should be student-directed, (c) teachers act as a facilitator, (d) all individuals' ideas and ways of thinking are valued, (e) the curriculum is flexible focusing on depth over breadth, and (f) focus should be on conceptual learning and application. On the other hand, a traditional perspective consists of the following principles: (a) students enter the classroom as "blank slates," (b) learning occurs through teacher-prescribed activities, (c) teachers act as a dispenser of knowledge, (d) learning occurs by independent work and rote memorization, (e) the curriculum is fixed focusing on breadth over depth, and (f) focus should be on basic foundational skills (Sampson et al., 2013).

Table 2.1

Dimensions of Traditional and Reformed Minded Beliefs Associated with Each Subscale of the BARSTL.

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

Note: Taken from Sampson et al. (2013)

Theory of Planned Behavior

The Theory of Planned Behavior (TPB) establishes an indirect link between an individual's salient beliefs (i.e., behavior, normative, and control beliefs) and enacted behaviors. Ajzen (1991) stated that "it is these salient beliefs that are considered to be the prevailing determinants of a person's intentions and actions" (p. 189). The proposed relationship between salient beliefs and behavior is shown in Figure 2.1.

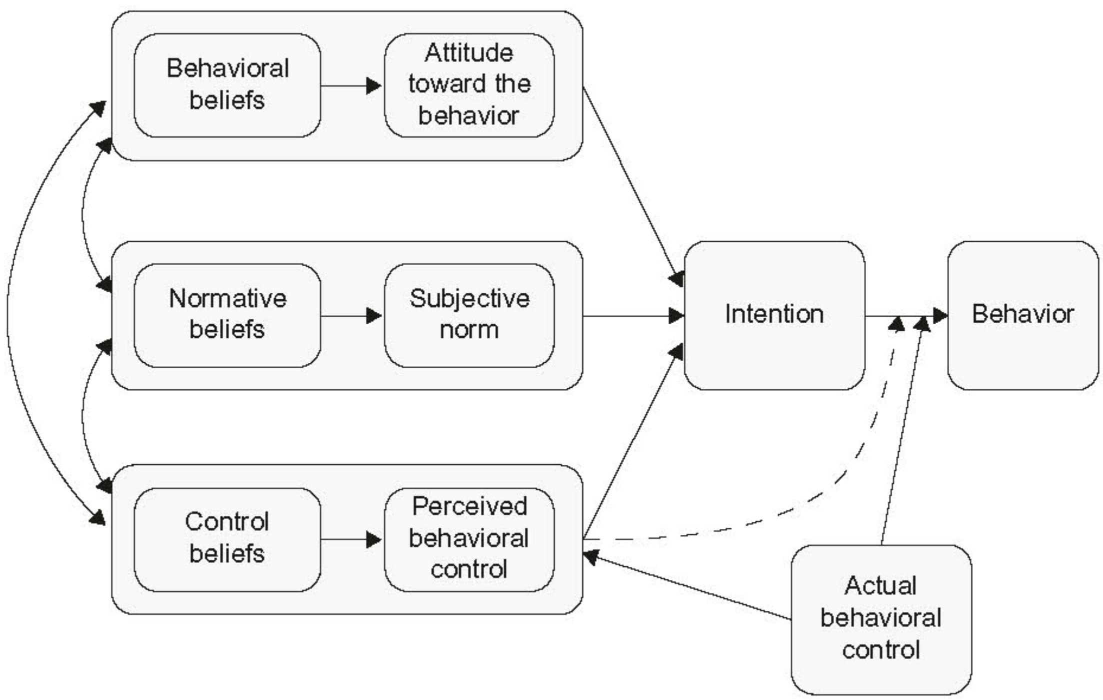

Figure 2.1. Visual representation of the Theory of Planned Behavior showing the relationships between salient beliefs and behaviors. Used from Smith, Smith, and Banilower (2014, p. 83) with permission by Springer.

The antecedent salient beliefs individuals hold develops the attitudes, subjective norms, and perceived behavioral control associated with a given behavior. Each of the following three factors then influences intentions, which according to the TPB supports, the notion that "actions…are controlled by intentions" (Ajzen, 1985, p. 11). The first factor, *attitudes*, develop from behavioral beliefs regarding the expected outcome and subjective values towards a given outcome. Ajzen (1991) stated that "attitudes develop reasonably from beliefs people hold about the object of the attitude" (p. 191). From this perspective, all behavioral beliefs and subjective value an individual holds link behaviors to positive or negative attitudes, resulting in a "belief-based measure of attitude" (Ajzen, 1991, p. 191). This belief-based measure of attitude includes either favorable or unfavorable evaluations of a given behavior. For example, a teacher believes that doing a student-centered lesson will result in a chaotic classroom. If this teacher associates a negative value to a chaotic classroom, then the overall attitude towards student-centered lessons may also be negative. If in addition to the previous subjective value, the teacher also holds a strong belief that doing a student-centered lesson will result in increased student learning, one belief might outweigh the other resulting in an overall positive attitude towards this particular behavioral belief.

The next factor that influences an individual's intention is the *subjective norm* surrounding a behavior. Subjective norms develop from normative beliefs, an individual's belief about other influential people or group's perception that they should or should not perform a given behavior. That is, the perception of social pressure within a given context, towards either performing or not performing a behavior and each individual's motivation to comply with the social pressure. Continuing our previous example, if the school district promotes student-centered lessons and the given teacher is motivated to comply, than the teacher will hold a more positive subjective norm towards that behavior. Conversely, if the school district does not promote student-center lessons, then the teacher might hold a less positive or negative subjective norm towards that behavior, depending on the motivation the teacher holds towards complying with social pressure.

The last factor influencing intention is *perceived behavioral control* developing from control beliefs held internally or externally by an individual. Control beliefs consist of the "presence or absence of requisite resources and opportunities" (Ajzen, 1991, p. 196). More specifically, control beliefs develop from past experiences, secondhand information, perceived difficulty, and other perceived factors influencing an individual ability to perform a behavior. An individual has a higher perceived behavioral control when there is an increase in resources and a decrease in obstacles impeding that behavior. Keeping with our example, if the teacher does not have the resources at the school to do a student-centered lesson, then that teacher will have a low perceived behavioral control.

Each of the previously described factors influences one another as well as an individual's intention towards a given behavior. Intention, along with actual behavioral control, influences the behavior, or action, taken. It is also important to understand that one factor of the TPB, behavior beliefs regarding the teaching and learning of science, will be used to define the cases in which classroom practices will be explored. Thus, it is important that the relationship between beliefs and practices be established, while still allowing for alternative explanations based on the cultural context. The TPB is particularly valuable by providing a framework to help understand why some beliefs are enacted, congruency between beliefs and practice, and others are not, incongruency between beliefs and practice. The TPB allows for contextual factors, the teachers own subjective values, the perceptions of other important and influential stakeholders, and the extent to which teachers' perceive control (or not) over factors which ultimately influences their enacted classroom practice.

Lesson Plans

While the relationship between teachers' beliefs and classroom practice is still unresolved, researchers have investigated the connection between teacher lesson plans and resulting classroom practice (e.g., Cai & Wang, 2006; Goldston, Dantzler, Day, & Webb, 2013; Jacobs, Martin, & Otieno, 2008; Li, Chen, & Kulm, 2009; Panasuk & Todd, 2005). Reviewing teacher lesson plans allows for analysis of larger chunks of instructional time with the view of both teacher decision making and sequencing (Jacobs et al., 2008). Typical lesson plans used as a way to evaluate teachers are brief and emphasize procedural aspects of teaching (Cai & Wang, 2006; Jacobs et al., 2008), but can be used to discern the decisions teachers make regarding the importance of content and pedagogical approaches (Li et al., 2009). The Science Lesson Plan Rating Instrument (Jacobs et al., 2008), 5E ILPv2 Instrument (Goldston et al., 2013), and Lesson Plan Evaluation Rubric (Panasuk & Todd, 2005) represent quantitative approaches for looking at the quality of instructional approach and connection to instructional practice observed in the classroom. While these instruments do exist, the nature of this study is explorative thus a qualitative approach was used to study lesson plans as a way to explore classroom practice.

In summary, taking the work done by Sampson, et al. (2013) and an understanding of teacher beliefs and practice, the relationship between teachers' beliefs, whether traditional or reform-based, and their classroom practice is still unresolved and inconclusive. This dissertation seeks to explore both the teachers' belief and classroom practice as a way to better understand this complex relationship.

Summary

The discussion of the constructs of teacher beliefs, classroom practice, and the relationship between the two illustrates the extensive, complex, and inconclusive nature of these constructs. Teachers' beliefs are viewed on a continuum, dynamic with time, and complex in nature and connectedness. The history of science educational reform demonstrates the need for continued effort as the educational system evaluates, analyzes, and addresses concerns as our national educational landscape continues to change. Research findings are varied as to whether teachers' beliefs and classroom practice are congruent or not. Therefore, this dissertation adds to the knowledge base by utilizing a reformed science teaching and learning construct presented by Sampson et al. (2013) as a way to view beliefs and classroom practice from a cultural perspective (Douglas, 1970, 1973, 1982; Harris, 2006).

CHAPTER III

STUDY 1: SECONDARY SCIENCE TEACHERS' BELIEFS ABOUT SCIENCE TEACHING AND LEARNING: AN APPLICATION OF GRID AND GROUP THEORY

Targeted Journal: School Science and Mathematics Journal

Abstract

Research examining the relationship between teachers' beliefs and classroom practice has been on the rise. To understand this relationship, we must first explore teacher beliefs. This study utilizes the Beliefs About Reformed Science Teaching and Learning (BARSTL) (Sampson et al., 2013) instrument as a way to (a) determine what secondary science teachers' believe and (b) apply Grid and Group theory (Douglas, 1970, 1973, 1982; Harris, 2006) as a way to categorize teachers based on their beliefs. Demographic information and BARSTL scores were collected from thirty-nine secondary science teachers at a large Midwestern state school district. Using Grid and Group typology, a resulting cultural map of BARSTL scores allowed for visualization of the different beliefs across the district and an illustration of demographic differences. Results indicate a statistical difference for education level and the number of undergraduate science courses taken. Results support further investigation into the groupings of teachers based on beliefs as a way to investigate the relationship between beliefs held and their classroom practice.

The current literature that investigates the relationship between teachers' beliefs and other outcomes is extensive (e.g. Ashton, 2015, Bryan 2012, Pajares, 1992) but it is not conclusive (e.g., Bryan, 2012; Buehl & Beck, 2015; Fang, 1996; Skott, 2015). Many researchers (e.g., Bryan, 2012; Fang, 1996; Pajares, 1992; Skott, 2015) have discussed issues, both theoretical and methodological, regarding the investigation of teachers' beliefs. Considering the reform initiatives emerging in science education and the established influence teacher beliefs can have on classroom practice (e.g., Cotton, 2006; Cronin-Jones, 1991; Driel et al., 2005; Wallace, 2014; Yerrick et al., 1997), understanding what teachers believe before exploring the exact nature of the belief and classroom practice relationship remains paramount (Bryan, 2012).

As our nation's schools implement new standards and curriculum based on current research (National Research Council, 2012; NGSS Lead States, 2013), exploring teachers' beliefs remains an important line of research. With the release of the *A Framework for K-12 Science Education* (National Research Council, 2012) and the *Next Generation Science Standards* (NGSS Lead States, 2013), the message continues to be the same, "K-12 science education in the United States fails to achieve [reform] outcomes" (National Research Council, 2012, p. 1). Researchers have proposed several explanations for why the nation continues to struggle towards achieving the goals set forth by the reform initiative, these include: (a) accessibility for traditionally underserved populations (Lee et al., 2014), (b) lack of proper teacher preparation and professional development (National Research Council, 2012), (c) increased high stakes testing (Whitford & Jones, 2000), and (d) incongruence of teacher beliefs and practice (Bartos & Lederman, 2014; Bryan, 2012; Cronin-Jones, 1991; de Jong, 2008; Fang, 1996; Greene et al., 2008; Potari & Georgiadou–Kabouridis, 2008; Sampson et al., 2013).

To understand fully the relationship between teachers' beliefs and their enacted classroom practices, we must first understand the beliefs teachers hold towards the teaching and learning of science. Teachers' beliefs are critical to the understanding of teachers' progress towards reformed science teaching and learning (Sampson et al., 2013) because beliefs act as a filter through which classroom practices are enacted (Crawford, 2007). In order to do so, exploration of teachers' beliefs should proceed through the consideration of their context (Fang, 1996).

Teachers work in a context-bound environment, the classroom, school, and district, in which their beliefs and classroom practices are negotiated daily. Each context has a unique culture in which individuals work and are influenced (Harris, 2005). Schools have culture(s) so it is important to understand how teachers' beliefs work within and are influenced by the culture. Smith, Smith, and Banilower (2014) suggested that future research examine classroom practice established by the grouping of teachers by beliefs as a way to begin investigating the factors that mediate the relationship between beliefs and practice.

The purpose of this survey study was to explore teachers beliefs about science teaching and learning by (a) determining belief characteristics of demographic differences from secondary science teachers at a large Midwestern school district and (b) the application of Grid and Group theory (Douglas, 1982; Harris, 1995, 2005, 2006) to establish a contextual comparison for teachers beliefs. Grid and Group theory (Douglas, 1982; Harris, 1995, 2005, 2006) establishes the study's theoretical framework for categorization of social contexts based on two dimensions, Grid and Group. The following research questions guide this study:

1. What are in-service secondary science teachers' beliefs about the teaching and learning of science?
    a. Is there a significant difference in the Beliefs about Reformed Science Teaching and Learning (BARSTL) scores and teachers' demographics (i.e., gender, race, highest education level, and current grade taught)?
    b. Does years of teaching experience predict BARSTL scores?
2. What is the resulting Grid and Group cultural map when using teachers' beliefs as measured by the BARSTL?
    a. Does the Grid and Group cultural map show demographics differences between teacher beliefs as measured by the BARSTL?
    b. How do the dimension of Grid and Group explain teachers' beliefs about reformed science teaching and learning as measured by the BARSTL?

The use of a context-based cultural approach provides a new perspective to the investigation of secondary science teachers' beliefs and the influence of larger demographic trends. This study seeks to begin the exploration into teachers' beliefs about the teaching and learning of science from a context-based cultural perspective.

Review of Related Literature

To provide context to the focus and purpose of this study, a review of literature around teachers' beliefs and reformed science teaching and learning will center this study within the field. We acknowledge that a relationship, while still not clear (Bryan, 2012), exists between teachers' beliefs and classroom practice, this relationship falls outside the scope of this study.

Teacher Beliefs

The construct and definition of teacher beliefs has not been consistently used throughout the literature (Bryan, 2012). This study defines teachers' beliefs as "their convictions, philosophy, tenants, or opinions about teaching and learning" (Milner, Sondergeld, Demir, Johnson, & Czerniak, 2011, p. 113). Beliefs compose a group of psychological constructs which "describe the structure and content of human thought" (Bryan, 2012, p. 487) that has an assumed relationship with a person's actions (Ajzen, 1985, 1991, 2012). Work done by Rokeach (1968), Green (1971), Nespor (1987), and Pajares (1992) have emerged as influential documents in the contextualization of beliefs within science education. Bryan (2012) used these foundational works to identify the following assumptions regarding science teacher beliefs:

- Beliefs do not exist in complete independence of one another, but are structured into an "internal architecture" of systems that are psychologically, but not necessarily logically organized.
- Not all beliefs are of equal importance to the individual. They are prioritized according to their relationship to other beliefs or other cognitive and affective structure.
- Beliefs are held along a continuum of centrality – some are more central, core, or primary, than others. It follows that the more central a belief is, the more resistant to change that belief will be.
- When a belief is changed, the centrality of that belief has repercussions for the entire belief system.
- Beliefs are far more influential than knowledge in discerning how individuals frame and organize tasks and problems and are stronger predictors of behavior (p. 478-479).

Kagan (1992) identified two main research agendas in the research into teachers' beliefs: teachers' sense of self-efficacy and content-specific beliefs. Teacher self-efficacy refers to the beliefs regarding their ability to influence students and their ability to perform certain professional tasks (Bandura, 1977). Content-specific beliefs focus on a teacher's "orientation to specific academic content [and includes] his or her judgments about appropriate instructional activities, goals, forms of evaluation, and the nature of student learning" (Kagan, 1992, p. 67). The focus of this study will be on content-specific beliefs about science teaching and learning. The study will not focus on teachers' self-efficacy regarding the beliefs that they hold, rather exploring what content-specific beliefs they hold regarding the teaching and learning of science.

The effect that teachers' beliefs have on the teaching and learning of science is well established (Bryan, 2012; Cotton, 2006; Cronin-Jones, 1991; Driel et al., 2005; Olson, 1981; Wallace, 2014; Wallace & Kang, 2004; Wallace & Priestley, 2011b; Yerrick et al., 1997). Research exploring the effect that teachers' beliefs have on classroom practices has indicated either a congruence or incongruence between the two, influenced by contextual factors (Bryan, 2012). Two clarifications should be noted: 1) beliefs can be determined either by self-reported claims, or espoused beliefs, or inferred from teacher practice (Bryan, 2012) and 2) a difference exists between beliefs "based on evaluation and judgment" and knowledge based on "objective fact" (Pajares, 1992, p. 313). There are several existing instruments (e.g. Teacher Beliefs about Effective Science Teaching (Smith et al., 2014), Beliefs About Reformed Science Teaching and Learning (Sampson et al., 2013), Teacher Belief Instrument(Luft & Roehrig, 2007), Views of Nature of Science (Lederman et al., 2002)) that focus on teachers' beliefs about science. Additionally, the importance of measuring and changing teachers beliefs can be linked to increases in student outcomes (e.g., Muijs & Reynolds, 2002), change in instructional practices (e.g., Abrami et al., 2004), and successful implementation of curriculum (e.g., Cronin-Jones, 1991). While the implications of teachers' beliefs beyond the relationship between self-reported classroom practice is important, this study only seeks to explore how the two constructs are related.

Science Teaching and Learning

The research community's understanding of effective science teaching and learning is extensive, complex, and messy (Lucero et al., 2013). It is important to have a discussion of science educational reform in relation to both previous and current understandings of effective science teaching and learning to frame this study. By doing so, this study seeks to structure the spectrum of teacher beliefs, from traditional to reformed, within a cultural-context based perspective.

The progressive educational reform movement that brought science to the forefront of public education began with the Committee of Ten (Bohan, 2003; DeBoer, 1991) and continued with the release of *A Nation at Risk* (National Commission on Excellence in Education, 1983). Continuing to build on the idea of enhancing science education within America, the following series of documents were released, each with their own evolving goals: *Science for All Americans* (American Association for the Advancement of Science, 1990), the *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993), the *National Science Education Standards* (NSES) (National Research Council, 1996), the *Framework for K-12 Science Education* (National Research Council, 2012), and *Next Generation Science Standards* (NGSS) (NGSS Lead States, 2013). Each promoted ways of teaching and learning (e.g. constructivism, inquiry, research, investigation, guided discovery, and scientific practices) of science that is consistent with our developing understanding of how students learn science (Lucero et al., 2013; Sampson et al., 2013).

Based on the foundational work of John Dewey (1916) and Jean Piaget (1936), constructivism refers to a philosophical understanding of how effective learning occurs within classrooms, “knowledge is not transmitted directly from one knower to another, but is actively built up by the learner” (Driver et al., 1994, p. 5). Science classrooms that use constructivist principles are student-centered and teacher-facilitated where students learn in collaborative grouping in which students discuss various approaches to a given problem or situation (Von Glasersfeld, 1989). Learning becomes an active, social process that requires students to make sense of experiences and “is something students do, not something that is done to them” (National Research Council, 1996, p. 22). Students in these types of classrooms are engaged in open-ended and student-centered activities. Students are allowed to explore a topic, while learning how science is conducted (Smolleck et al., 2006). Moreover, the teacher “models the skills of scientific inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterize science” (National Research Council, 2000b, p. 22). Most recently, *A Framework for K-12 Science Education* (National Research Council, 2012), builds on previous work with central principles that include “young children’s capacity to learn science, a focus on core ideas, the development of true understanding over time, the consideration both of knowledge and practice, the linkage of science education to students’ interests and experiences, and the promotion of equity” (National Research Council, 2012, p. 24).

Reformed Beliefs about Science Education. This study utilizes Sampson, Enderle, and Grooms (2013) construct of “reformed beliefs about science education” (Sampson et al., 2013, p.

6) defined as the "degree to which science teachers' beliefs about the teaching and learning of science are aligned with the current reform movement in science education" (Sampson et al., 2013, p. 5). This construct is measured by the Beliefs About Reformed Science Teaching and Learning (BARSTL) questionnaire (Sampson et al., 2013) that divides the construct into four subscales: (1) how people learn about science, (2) lesson design and implementation, (3) characteristics of teachers and the learning environment, and (4) the nature of the science curriculum. Each subscale differentiates reformed and traditional perspectives within the overarching construct (see Table 3.1). Sampson, Enderle, and Grooms (2013) described a reformed perspective consistent with the following principles: (a) ideas students bring into the classroom influence learning, (b) learning should be student-directed, (c) teachers act as a facilitator, (d) all individuals' ideas and ways of thinking are valued, (e) the curriculum is flexible focusing on depth over breath, and (f) focus should be on conceptual learning and application. On the other hand, a traditional perspective consists of the following principles: (a) students enter the classroom as "blank slates" (b) learning occurs through teacher-prescribed activities, (c) teachers act as a dispenser of knowledge, (d) learning occurs by independent work and rote memorization (e) the curriculum is fixed focusing on breath over depth, and (f) focus should be on basic foundational skills (Sampson et al., 2013). Although similarities between the Framework and BARSTL subscales exist, it is not the objective of this study to evaluate the degree to which the subscale perspectives match that of more current literature. Rather, the objective of this study is to explore how the BARSTL subscales and overarching construct of the teaching and learning of science help explore teacher beliefs within our context.

Table 3.1

Dimensions of Traditional and Reformed Minded Beliefs Associated with Each Subscale of the BARSTL.

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

Note: Used from Sampson et al. (2013) with permission by John Wiley and Sons.

Theoretical Perspective

The relationship between beliefs and practice is complex and disputed, therefore this study adopts the perspective of our context, in this case a school district, as a unique culture. The Webster Dictionary defines culture as (a) the beliefs, customs, arts, etc. of a particular society, group, place, or time, (b) a particular society that has its own beliefs, ways of life, art, etc., and c) a way of thinking, behaving, or working that exists in a place or organization (such as a business) (Culture, n.d.). Pajares (1992) asserted that “beliefs are created through a process of enculturation and social construction” (p.316). Culture can be viewed from three different perspectives: (1) a holistic approach taking a comprehensive explanation of culture; (2) a symbolic approach where a context comprised of people has a set of shared beliefs, complex rituals, and relationships; and (3) a dualistic approach emphasizing that in all social contexts, people have knowledge, feelings, beliefs, and values that impact the way they act (Harris, 2005). In an effort to provide an applicable educational context, Harris (2005) discussed culture as “defin[ing] the essence of the school and gives meaning to human endeavor” (p. 32). Harris (2005) stated that culture encompasses the entire educational process, specifically the values, beliefs, norms, and social patterns of all members of the school community” (p.32). Synthesizing these ideas and beliefs act as the establishment of culture(s) within a classroom, school, and/or district.

Douglas’ (1982) Grid and Group theory provides a theoretical framework that allows for the classification and comparisons of social contexts from a cultural perspective while considering the “contextual nature of teachers’ beliefs” (Bryan, 2012, p. 480). Overtime, Douglas (1970, 1973, 1983) refined Grid and Group theory to allow for a typology that enables researchers to “meet the conceptual and methodological challenges inherent in cultural inquiry and educational practice” (Harris, 1995, p. 619). Utilizing this framework, an *a priori* framework was established to categorize teachers’ beliefs as measured by the overarching construct and subscales of the BARSTL. The following section describes relevant aspects of Grid and Group theory.

Grid and Group Theory

Douglas (1982) asserted that when investigating social context, researchers must look at how individuals generate, catch, and transform meanings that are embedded and context-bound. Furthermore, the social context in which an individual resides influences beliefs that guide decision-making processes that justify the interactions with both individuals and the context-bound culture. From this, Douglas (1982) constructed two dimensions to describe the “full array of possible social structures” (p. 190). These two constructed dimensions, Grid and Group, described one way to understand social contexts bounded by meanings individuals hold that influences interactions. A cultural map showing the continuum of both dimensions (see Figure 3.1) creates four distinct social contexts. Descriptions of each of the four different social contexts are developed from the characteristics of the strong- or weak-grid and strong- or weak-group dimension.

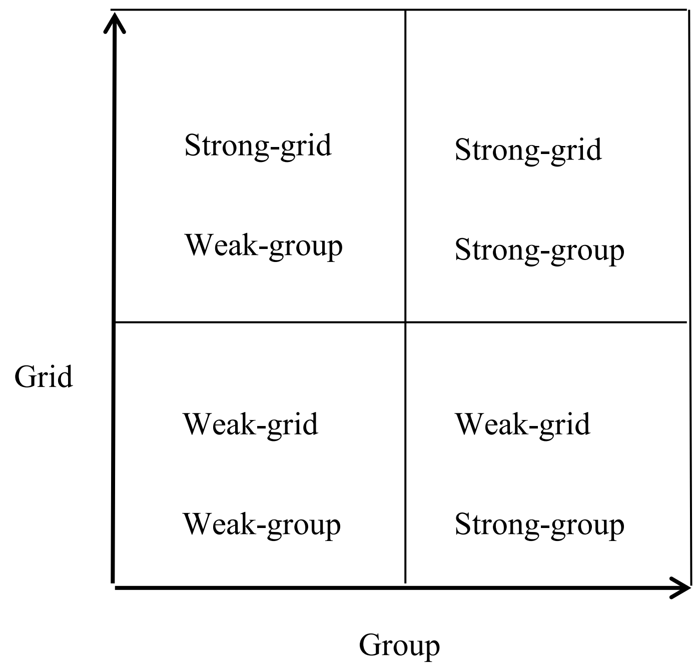

Figure 3.1. Mary Douglas's (1982) four types of social contexts shown on a cultural map established by a continuum of Grid and Group characteristics

Grid is first described as "a dimension of individuation" (Douglas, 1982, p. 190). This dimension establishes how the "progressive change in the mode of control" (Douglas, 1982, p. 192) influences the individuals. The constructed dimension establishes a continuum from each extreme, strong-grid to weak-grid. A strong-grid describes a context where visible rules establish a segregation between interactions and rank that keep individuals apart restricting and regulating their interactions and options (Douglas, 1982). Moving towards a weak-grid context, individuals are not segregated; rather, each individual is able to negotiate their own interactions more freely providing “the unique value of the individual person” (Douglas, 1982, p. 198).

Douglas (1982) first described the group dimension as “social incorporation” (p. 190). Furthermore, the group dimension of social contexts considers “the individual’s life is absorbed in and sustained by group membership” (Douglas, 1982, p. 202). In a strong group dimension, individuals are incorporated together in the group with shared work, resources, and context (Douglas, 1982). Moving towards a weak group dimension, the focus shifts to advancement of the individual (Douglas, 1982).

Grid and Group Theory from an Educational Prospective

Taking Douglas’s (1982) Grid and Group theory, Harris (1995, 2005, 2006) further developed the theoretical framework to view how Grid and Group dimensions helped to understand school culture. For Harris (1995, 2005, 2006), a strong grid context consisted of having minimal autonomy, specifically defined roles, rules and responsibilities, and a centralized power and authority. Typically, teachers within this context do not have freedom to select or adapt their own curricula and textbooks; roles are fixed and established with hierarchal layers that insulate one role from the other. Conversely, Harris (2006) described a weak grid context consisting of maximum autonomy, loosely defined roles, rules, and responsibilities, and decentralized power and authority. In this case, teachers have more autonomy to choose their curricula, textbooks, and instructional methods; roles are achieved; individuals are free to negotiate their own relationships within the context; and individuals are valued for skills, behaviors, and abilities.

For Harris (1995, 2005, 2006), the group dimension referred to "the degree to which people value collective relationships and the extent to which they are committed to the larger social unit" (Harris, 2005, p. 36). Harris (2006) described a strong group context as one with strong allegiance, pressure to consider group goals and activities, strong social incorporation, and a focus on the social collective over individual members. Harris (2006) described a low group context as one in which there is weak allegiance, minimal pressure to consider the group, minimal social incorporation, and individuals are prioritized over the group.

Utilizing Douglas's (1982) framework to create a typology helps to situate an individual within a social context defined by the members and interaction. Through the process of establishing a typology, individuals within each context hold specific characteristics but are not necessarily defined by all characteristics of the classification. Individuals within a context, can then be placed within different groups, defined by Grid and Group dimensions, in order to describe individuals' "beliefs locked together into relational patterns" (Douglas, 1982, p. 199). Through this theoretical framework, teachers' beliefs are situated in a social context enabling exploration into how teachers' beliefs vary within and establish a given context. This study will focus on exploring how teachers' beliefs vary within the context of a school district.

Methodology

The study utilized a survey design to explore secondary science teachers' beliefs about the teaching and learning of science. This approach will provide a numerical representation of teachers' beliefs gathered with the intent to: (a) generalize to the school district population of secondary science teachers and (b) establish the usefulness of a Grid and Group cultural map to investigate teachers' beliefs. Institutional Review Board approval was obtained prior to data collection (see Appendix A).

Participants

Thirty-nine secondary science teachers at a large district in a Midwestern state participated in the study. Their teaching experience ranged from one to 31 years of experience with a mean of 11.74 years (SD = 7.62). Table 3.2 describes the demographic characteristics of the sample population. Teacher participants were selected based on the following criteria: (a) current teaching assignment, (b) teaching assignments contained at least one science discipline (physical, biological, and/or earth and space sciences), and (c) not employed as a substitute or emergency replacement. Teachers were identified through a clustering procedure (Creswell, 2013) to create a convenient sample by identifying teachers within the district who matched the established criteria. The purpose and scope of the study was shared with participants to determine their willingness to participate in the study. All consenting teachers who met the qualifications were accepted into the study.

Table 3.2

Demographic characteristics of the sample population of secondary science teachers.

	Number	Percent		Number	Percent
Gender			Grade Level		
Male	7	17.95	6th	8	20.51
Female	32	82.05	7th	8	20.51
Race/Ethnicity			8th	9	23.08
American Indian/White	3	7.69	9th	6	15.38
American Indian	2	5.13	10th – 12th	8	20.51
Asian	1	2.56	Highest Education Level		
Native Hawaiian/Pacific Islander	1	2.56	Bachelor's	26	66.67
Black	5	12.82	Master's	12	30.77
White	27	69.23	Doctorate	1	2.56

Data Sources

This study consisted of a collection of two data sources: demographic information and scores on the Beliefs about Reformed Science Teaching and Learning (BARSTL) questionnaire (Appendix B) (Sampson et al., 2013).

Demographics. A collection of teachers' demographic information occurred at the same time as the BARSTL. While the demographic data collected was extensive, this study sought to focus on large demographic characteristics that would describe the sample as a whole. Thus, demographic information included in this study is as followed: gender, race, highest education level, and current grade taught (see Appendix C).

Beliefs about Reformed Science Teaching and Learning (BARSTL). This study utilizes Sampson, Enderle, and Grooms (2013) construct of "reformed beliefs about science education" (Sampson et al., 2013, p. 6) defined as the "degree to which science teachers' beliefs about the teaching and learning of science are aligned with the current reform movement in science education" (Sampson et al., 2013, p. 5). This construct is measured by the Beliefs About Reformed Science Teaching and Learning (BARSTL) questionnaire (Sampson et al., 2013) that divides the construct into four subscales: (1) how people learn about science, (2) lesson design and implementation, (3) characteristics of teachers and the learning environment, and (4) the nature of the science curriculum.

Each of the four BARSTL subscales has a score range from 8 (traditional) to 32 (reformed); traditional scores are 8-20 while reformed scores are 21-32. Each subscale is composed of eight statements, each with a score ranging from 1 (traditional) to 4 (reformed). Each statement is written to reflect either a traditional or reformed perspective. The scores on each statement will be used to identify specific participant beliefs within each subscale as a way to further develop a view into each teacher's belief, while also creating a total score that represents the overarching BARSTL construct.

During the initial validation, Sampson et al. (2013) established reliability by obtained two internal consistency estimates for the BARSTL: split-half coefficient expressed as a Spearman-Brown corrected correlation and coefficient alpha. Sampson et al. (2013) reported a split-half coefficient value of 0.80 and a coefficient alpha value of 0.77. Other studies using the BARSTL have determined similar coefficient alphas to that of Sampson et al. (2013): 0.75 (Karaman & Karaman, 2013), and 0.71 (Büyüktaskapu, 2010)(Büyüktaskapu, 2010). Content validity was established through a panel of experts evaluation of whether each statement on the BARSTL matched the current science education reform literature and measured wither a traditional or reformed perspective (Sampson et al., 2013). Lastly, construct validity was tested to support the development of four subscales with one overarching construct in two ways, 1) a positive correlation between each subscale score to the total score, and 2) an exploratory factor analysis showing four distinct factors matching that of the four subscales (Sampson et al., 2013).

Data Collection

Participants were recruited through in person discussions of the purpose of the study during a preexisting each grade level (6^{th} – 12^{th}) departmental meeting. After gaining informed consent, the researcher administrated the BARSTL and demographics survey in person.

Data Analysis

Teachers responses to the BARSTL were entered into SPSS (version 23) and numerically coded following the protocols established by Sampson, Enderle and Grooms (2013). To ensure and meet similar internal consistency measures (DeVellis, 2012) held for the BARSTL questionnaire with our population, the reliability was tested and compared to previous studies using a split-half coefficient expressed as a Spearman-Brown corrected correlation and coefficient alpha.

BARSTL Subscales and Overall Construct. For each teacher, subscale scores were computed by added the score from each of the eight statements with that subscale. The total BARSTL score was calculated by adding each of the four subscale scores. For each subscale and total score, the range, mean, median, and standard deviation was calculated and plotted in a box and whisker plot.

Demographic Analysis. One-way ANOVA's using SPSS were conducted on the following variables to determine differences between observed teacher beliefs as measured on each BARSTL subscale and total BARSTL score: gender, race, highest education level, and current grade taught. Due to demographic groups having varying numbers of participants in each, the one-way ANOVA assumptions were tested to ensure that the test held up for our sample. The ANOVA's were conducted as a way to explore demographic differences within our sample that resulted in a statistically significant difference for teacher beliefs as measured by the BARSTL. Additionally, a simple linear regression was performed looking at the correlation between years of teaching experience and each subscale and total score to explore if the number of years of teaching could predict teacher beliefs.

Grid and Group Typology. Using Douglas's (1982) theoretical framework of Grid and Group theory and Harris's (1995, 2005, 2006) application towards educational contexts, an *a prior* typology acted as a way to categorize teachers' beliefs as measured using the BARSTL subscale scores. The use of this theoretical framework allows for an interpretation of teachers' beliefs as based on contextual factors that govern culture, specifically school culture.

Utilizing this study's theoretical perspective, the BARSTL subscales of *lesson design and implementation* and *the nature of the science curriculum* match the criteria for the grid dimension (see Table 3.4). Looking at the BARSTL subscale distinctions between reform and traditional perspectives, a high-grid context consists of a traditional perspective where the curriculum is fixed and prescriptive, the classroom is teacher focused, and students and teachers are insulated from interaction. A low-grid context consists of a reformed perspective where the curriculum is flexible, learning is focused on conceptual and holistic understanding, the classroom is student focused, and classroom interactions focus on a collective effort in learning.

Table 3.3

Application of Grid typology to the dimensions of Traditional and Reformed prespectives associated with each subscale of the BARSTL.

BARSTL Subscales	Traditional Perspective	Reformed Perspective
	High Grid Context	*Low Grid Context*
Lesson design and implementation	Teacher-prescribed activities Frontal teaching – telling and showing students Relies heavily on textbooks and workbooks	Student-directed learning Relies heavily on student-developed investigations, manipluative materials, and primary sources of data
The nature of the science curriculum	Focus on basic skills (foundations) Curriculum is fixed Focus on breadth over depth	Focus on conceptual understanding and the application of concepts Currcium is flexible, chages with student questions and interst. Focus on depth over breadth

Note: Adapted from Sampson et al. (2013).

Conversely, the BARSTL subscales *how people learn about science* and *characteristics of teachers and the learning environment* describe the beliefs associated with the group dimension (see Table 3.5). In a high group context, learning occurs together through the respect and acknowledgement of individual's contribution to the learning environment. In a low group context, learning occurs as a competitive independent working environment where students' understandings do not influence the learning environment.

Table 3.4

Application of Group typology to the dimensions of Traditional and Reformed prespectives associated with each subscale of the BARSTL.

BARSTL Subscales	Traditional Perspective	Reformed Perspective
	Low Group Context	*High Group Context*
How people learn about science	Compared with "blank slates"	What students learn is inflenced by their existing ideas.
	Learning is accumulation of information	Learning is the modification of existing ideas.
Characteristics of teachers and the learning environment	The teacher acts as a dispenser of knowledge.	The teacher acts as facilitator, listener, and coach.
	Focus on independent work and learning by rote	Focus on learning together and valuing others ideas and ways of thinking.

Note: Adapted from Sampson et al. (2013).

Using this framework, a teacher's Grid (*lesson design and implementation* and *the nature of the science curriculum*) and Group (*how people learn about science* and *characteristics of teachers and the learning environment*) scores were determined by adding the two subscales composing each dimension. By doing so, the resulting Grid and Group scores now have a range of 16 (traditional) to 64 (reformed). More traditional beliefs score between 16 and 40, whereas a more reformed belief scores between 41 and 64. While the distinctions between a traditional or reformed perspective as represented by the Grid and Group scores seems as a rigid transition, this study maintains the perspective that teacher beliefs as measured by the BARSTL are on a continuum (Sampson et al., 2013) and that the interpretation of the Grid and Group typology (Douglas, 1970, 1973, 1982; Harris, 1995, 2006) should also be viewed as a continuum on both dimensions.

Each teacher's Grid and Group scores were plotted onto a cultural map (see Figure 3.2) (Mamadouh, 1999) creating a visual representation of the collective teachers' beliefs. While the creation of the cultural map creates areas in which teacher beliefs seem to be in conflict, this study seeks to explore what teachers believe and how these beliefs fit within our theoretical perspective. Specifically, it might seem counterintuitive within the Reformed-Traditional quadrant that a teacher could believe in student-directed learning while also believing that the teacher is the dispenser of the knowledge within the classroom. Additionally, a teacher might fall within the traditional-traditional quadrant but still hold beliefs that are considered reformed causing the teacher to be plotted between the two extremes. Utilizing Grid and Group theory (Douglas, 1970, 1973, 1982) to differentiate the construct of teacher beliefs as measured by the BARSTL, it is our position that these conflicts and intersections of beliefs could occur, supporting our exploration into this particular application. The resulting cultural map will provide a way to understand and compare the dynamic nature of the secondary science teachers' beliefs within the given context.

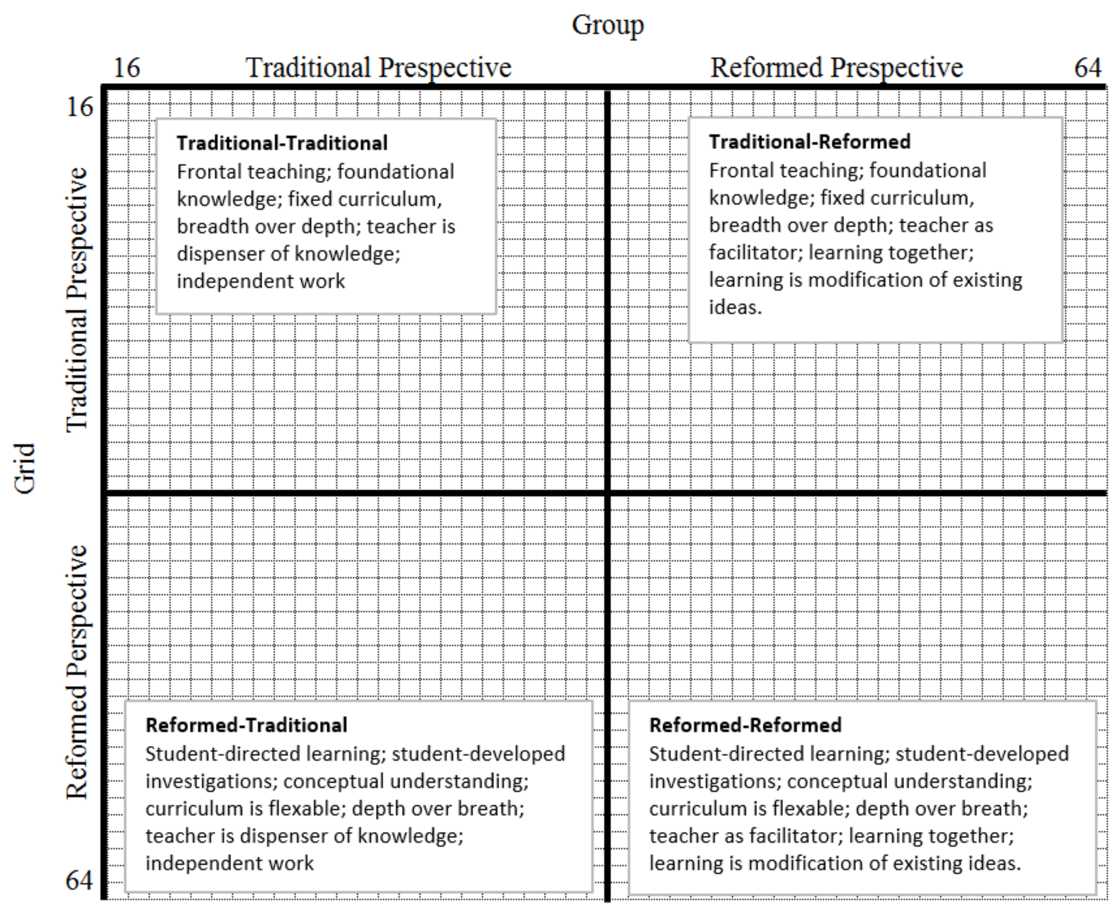

Figure 3.2. Grid and group plot showing sum of subscale scores and traditional and reformed perspective regions.

Results

The following section presents the results of our data analysis organized by research question: BARSTL scores, one-way ANOVA, simple linear regression, and Grid and Group typology. For our sample, the reliability analysis showed a 0.72 split-half coefficient and 0.78 coefficient alpha for the overall construct measured by each subscale, similar to those previously mentioned, indicating reliability of the BARSTL instrument for our population.

BARSTL Scores

Summarized BARSTL subscale (range 8 – 32) and total BARSTL scores (range 32-128) (see Table 3.6) suggested that the overall population held both traditional and reformed perspectives, with the mean leaning slightly towards the reformed perspective. The resulting box and whisker plots (see Figure 3.3 and 3.4) shows the range of scores for the population. As a whole, teachers held perspectives that are more reformed as measured by the BARSTL. The highest scoring subscale was *Characteristics of Teachers and the Learning Environment* (M=23.23, SD=2.43), while the lowest scoring subscale was *How People Learn About Science* (M=21.60, SD=2.62). Considering the range of the subscale scores, it is important to note that each subscale score average represented beliefs consistent with the reformed perspective, while still having teachers' scores represent a traditional perspective.

Table 3.5

Summarized BARSTL subscale and construct scores for secondary science teachers. n=39

Subscale	Minimum	Maximum	Median	Mean	SD
How People Learn about Science	16	28	21	21.60	2.62
Lesson Design and Implementation	18	26	22	21.99	1.97
Characteristics of Teachers and the Learning Environment	19	30	23	23.23	2.43
The Nature of the Science Curriculum	18	28	22	22.10	2.36
Overall BARSTL	75	106	89	88.92	7.10

Note: Scores are on a continuum between traditional (8 to 20 subscale, 32 to 60 overall construct) and reformed (21 to 32 subscale, 61 to 128 overall construct).

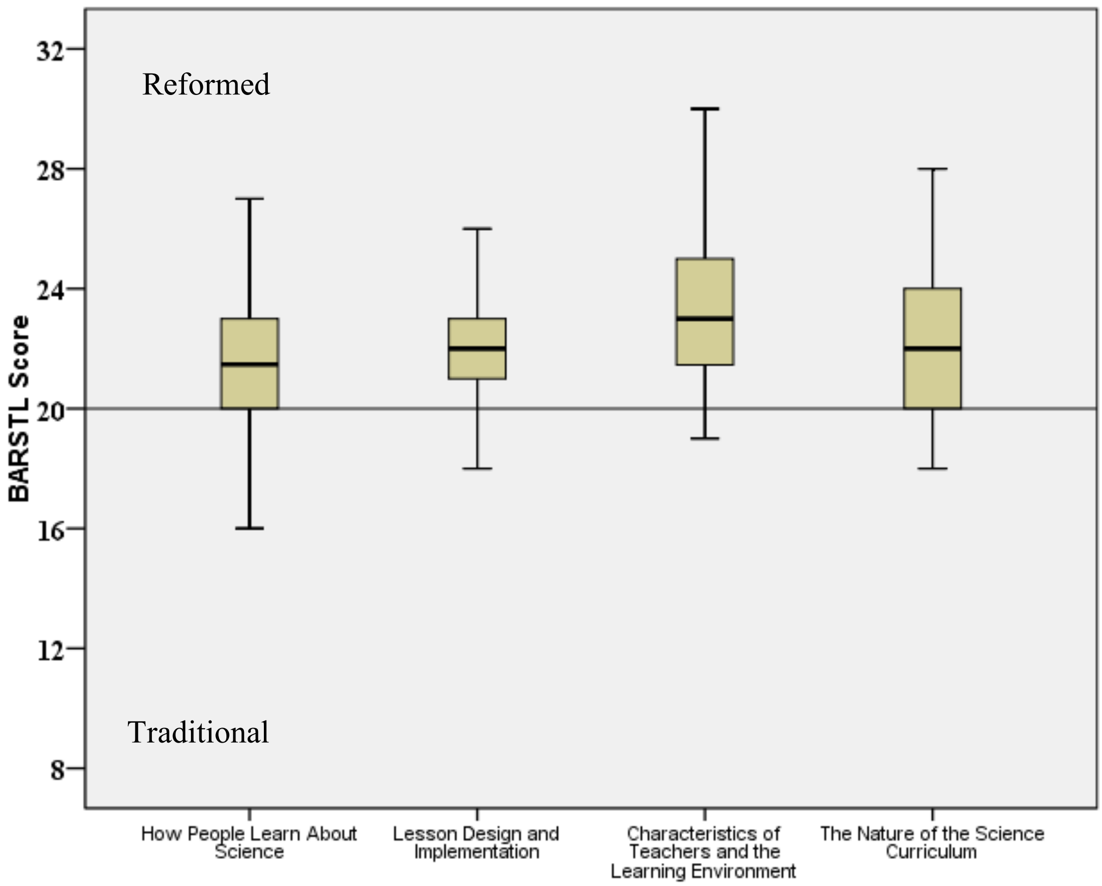

Figure 3.3. Box and whisker plot for each BARSTL subscale.

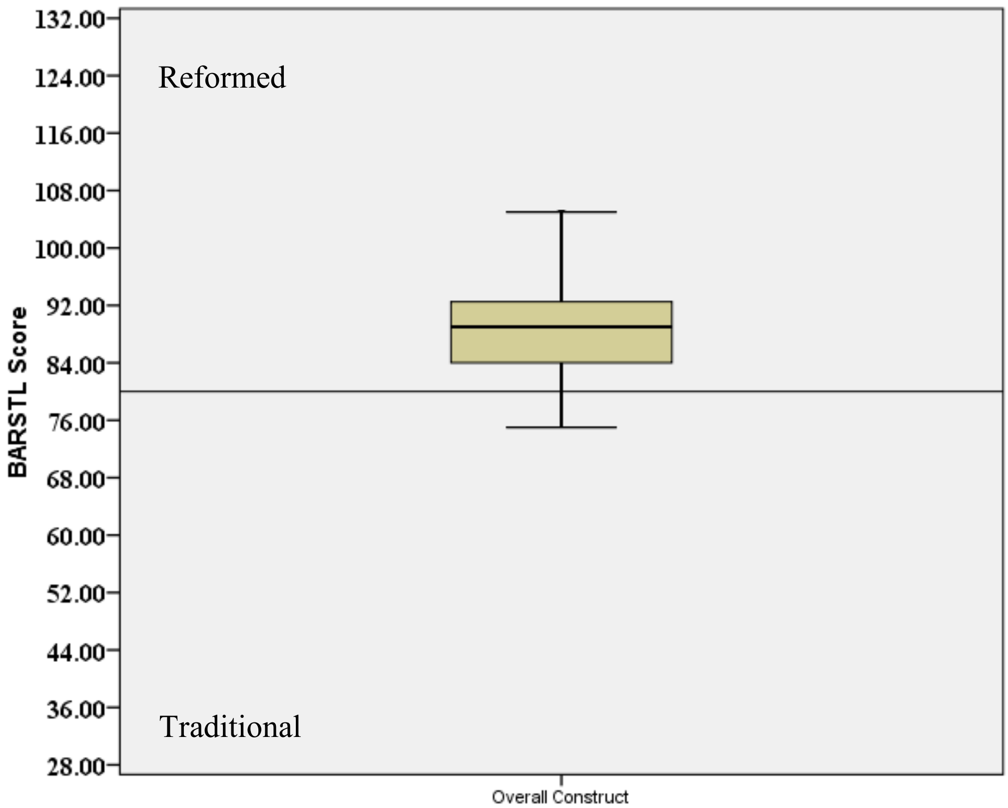

Figure 3.4. Box and whisker plot for overall BARSTL construct.

While looking at the overall averages for each subscale and overall construct is important, looking closer at what statements scored the highest and lowest shows the wide spectrum of beliefs. Looking more specifically at the scores for each statement within the subscales described previously shows three top scoring statements for the sample: *The science curriculum should help students develop the reasoning skills and habits of mind necessary to do science* (M=3.474, SD=0.4993), *In science classrooms, students should be encouraged to challenge ideas while maintaining a climate of respect for what others have to say* (M=3.385, SD=0.5436), and *Students develop many ideas about how the world works before they ever study* *about science in school* (M=3.33, SD=0.70). Each statement was written to reflect the reformed perspective of science teaching and learning. Conversely, the following are the lowest scoring three statement for the sample: *Students are more likely to understand a scientific concept if the teacher explains the concept in a way that is clear and easy to understand* (M=1.64, SD=0.54), *Experiments should be included in lessons as a way to reinforce the scientific concepts students have already learned in class* (M=1.85, SD=0.54), and *Students should know that scientific knowledge is discovered using the scientific method* (M=1.90, SD=0.64). These statements are written to reflect the traditional perspective, thus on average teachers agreed with these statements and their scores were reversed scored.

Demographic Results

The following section discusses the results obtained from the one-way ANOVA's on demographic differences and the simple linear regression on years of teaching experience.

ANOVA. Utilizing a one-way ANOVA test to explore the demographic differences within the sample, differences were observed for education level and number of undergraduate-level science courses. Due to unequal sample size for each of the demographic variables, a Shapiro-Wilk test of normality and Levene's test for homogeneity of variances reveled to not be significant for each test. The results of the one-way ANOVA tests are summaries in Table 3.7.

Table 3.6

Summary of statistical significant tests.

	df	F	η^2	*p*
Education Level				
Overall BARSTL	1, 37	11.419	0.236	**0.002****
How People Learn about Science	1, 37	5.884	0.137	**0.020***
Lesson Design and Implementation	1, 37	10.421	0.220	**0.003****
Characteristics of Teachers and the Learning Environment	1, 37	4.454	0.107	**0.042***
The Nature of the Science Curriculum	1, 37	4.205	0.102	**0.047***
Current Grade Taught				
Overall BARSTL	4, 34	1.023	0.107	0.410
How People Learn about Science	4, 34	0.333	0.038	0.854
Lesson Design and Implementation	4, 34	0.729	0.079	0.579
Characteristics of Teachers and the Learning Environment	4, 34	0.942	0.100	0.452
The Nature of the Science Curriculum	4, 34	1.442	0.145	0.241
Gender				
Overall BARSTL	1, 37	1.778	0.046	0.191
How People Learn about Science	1, 37	0.978	0.026	0.329
Lesson Design and Implementation	1, 37	0.000	0.000	0.985
Characteristics of Teachers and the Learning Environment	1, 37	2.245	0.057	0.142
The Nature of the Science Curriculum	1, 37	1.909	0.049	0.175
Race				
Overall BARSTL	4, 34	0.719	0.078	0.585
How People Learn about Science	4, 34	0.763	0.082	0.557
Lesson Design and Implementation	4, 34	0.217	0.025	0.927
Characteristics of Teachers and the Learning Environment	4, 34	1.759	0.171	0.160
The Nature of the Science Curriculum	4, 34	0.314	0.036	0.867

**Note:* *Significance of* $p<0.05$ *and* $p<0.01$ *are indicated.*

For the overall construct and each subscale, the individuals who held a master's degree held beliefs more aligned with the reformed perspective (higher values) than those who did not. Statistically insignificant differences were observed for each subscale and total scores for the remaining variables: current grade taught, gender, and race.

Simple Linear Regression. A simple linear regression (see Figures 3.5 and 3.6) for the number of years of teaching experience showed insignificant correlation for *How People Learn about Science* $R^2 = 0.037$, $F(1,37)=1.41$, $p = 0.24$; *Lesson Design and Implementation* $R^2 = 0.002$, $F(1, 37)= 0.091$, $p = 0.76$; *Characteristics of Teachers and the Learning Environment* $R^2 = 0.003$, $F(1,37)= 0.120$, $p = 0.73$; *The Nature of the Science Curriculum* $R^2 = 0.06$, $F(1,37)= 2.34$, $p=0.13$, and total score $R^2 = 0.002$, $F(1,37)= 0.071$, $p = 0.79$.

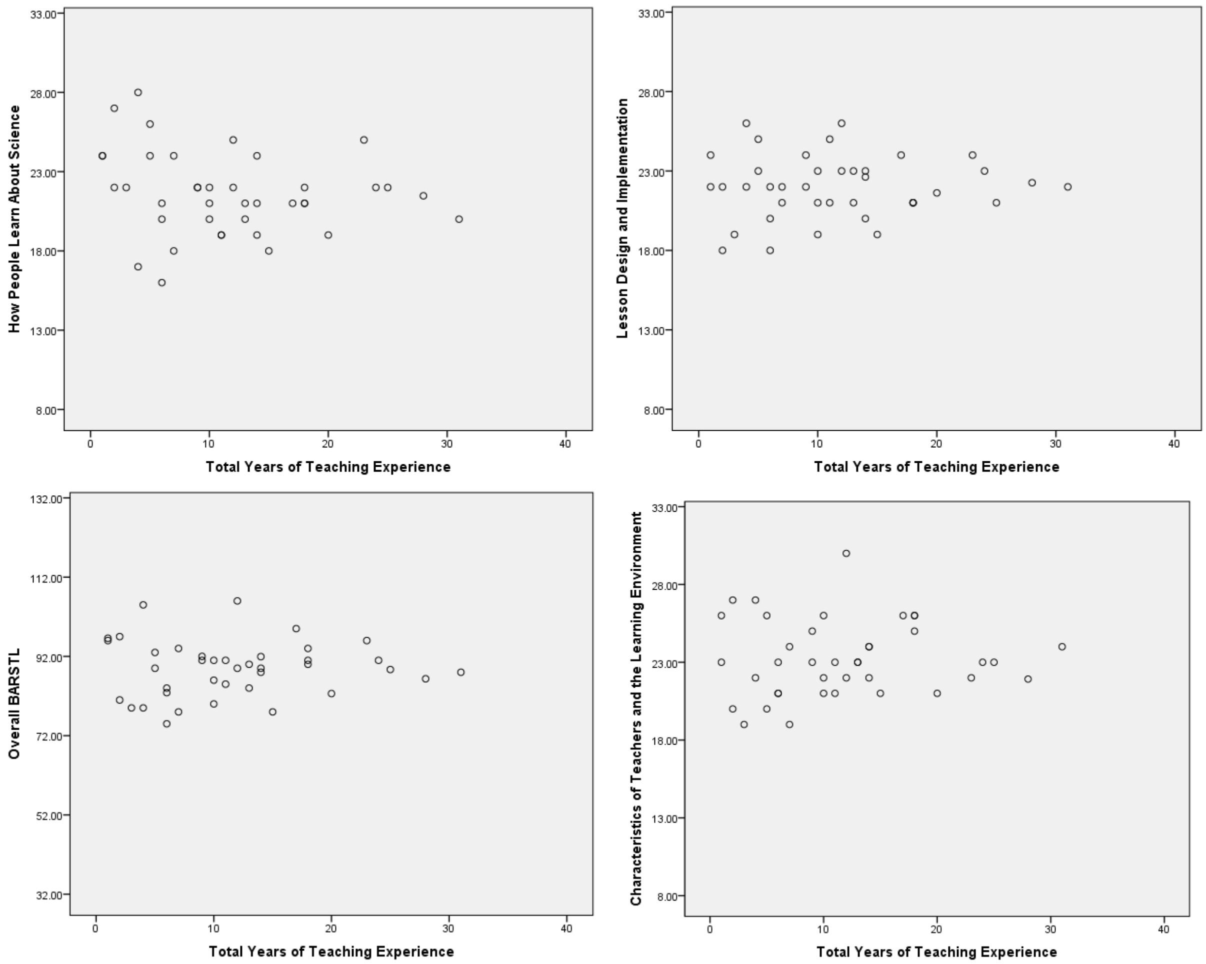

Figure 3.5. Scatter plot comparing years of teaching experience and each subscale score.

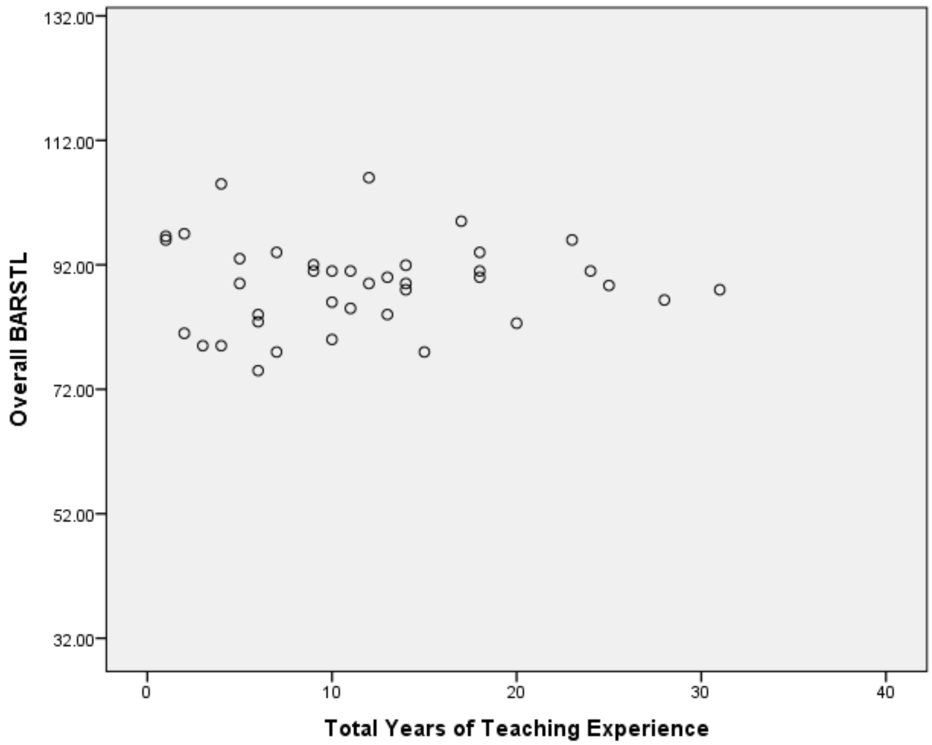

Figure 3.6. Scatter plot comparing years of teaching experience and overall BARSTL score.

Grid and Group

Plotting the Grid and Group scores (see Figure 3.7) for secondary science teachers allowed for a visual representation of teachers' beliefs between traditional and reformed perspectives. To show the difference observed from the statistically significant ANOVA previously described, Figure 3.7 shows teachers who held a master's degree as shaded in light-gray. Using the *a priori* theoretical framework to situate teachers' beliefs resulted in one cluster of scores as shown on Figure 3.7. Looking at each quadrant, three teachers fell into the traditional-traditional group, five into the traditional-reformed group, three into the reformed-traditional group, and twenty-eight into the reformed-reformed group. This placed one teacher with a master's degree into the reformed-traditional group and the remaining thirteen into the reformed-reformed group.

The comparison between the box and whisker plots (Figure 3.3 and 3.4) and the Grid and Group plot (Figure 3.7) reveals similar results, both show teachers beliefs extending for traditional to reformed. The majority of the teachers fall within the reformed-reformed quadrant while some still remain in a combination of traditional and reformed. The usefulness of the Grid an Group plot comes when the goal is to differentiate teachers into a selection matrix, resulting in four groups each defined by differences observed on two different continuums. The resulting selection matrix could be used in future research to explore the differences observed between the groups of teachers based on their beliefs.

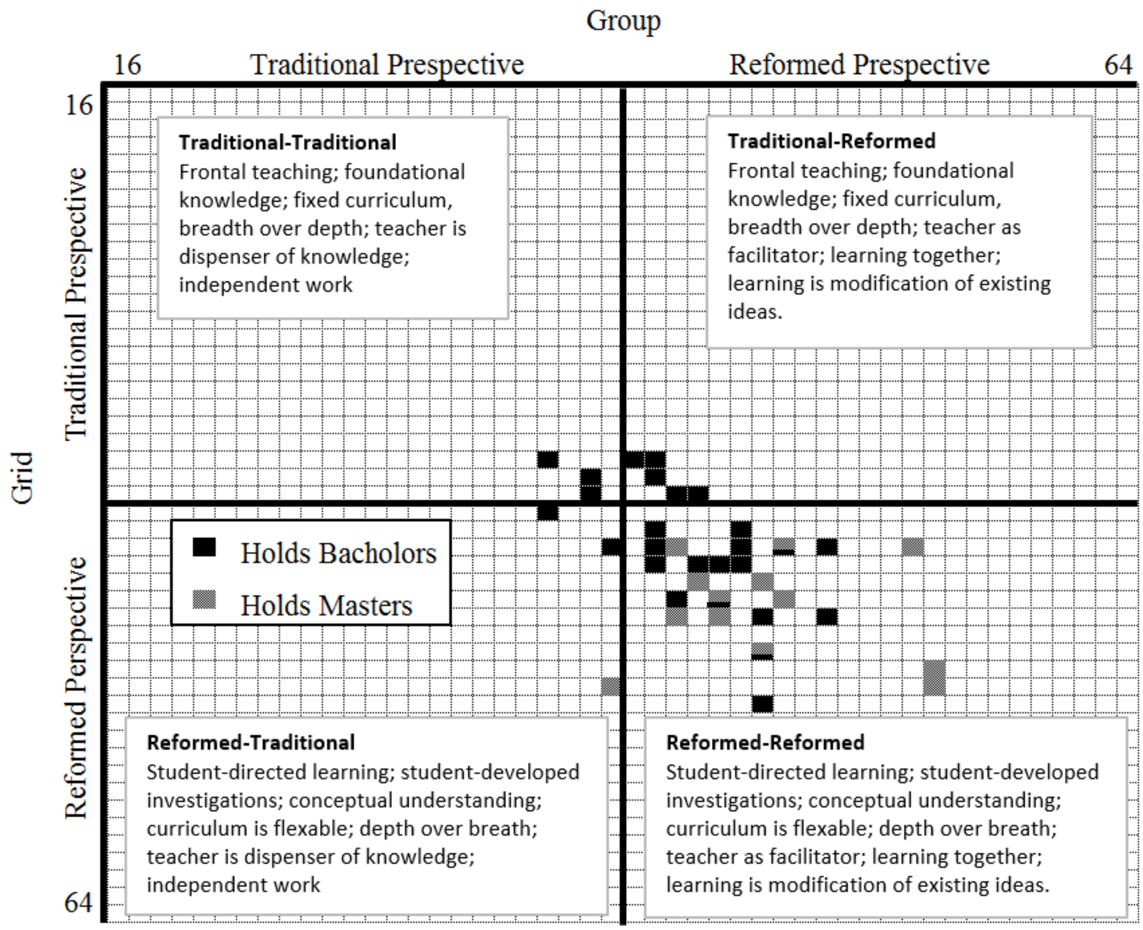

Figure 3.7. Grid and group plot for secondary science teachers. Teachers holding a master's degree are shaded.

Discussion

This study sought to explore the beliefs about science teaching and learning held by teachers at a large mid-western school district. Beliefs were analyzed for overall demographic similarities and differences as well as the application of an *a prior* Grid and Group typology (Douglas, 1970, 1973, 1982) to categorize teachers based on beliefs. In the following sections, each overarching research question is presented and discussed.

RQ1: What are in-service secondary science teachers' beliefs about the teaching and learning of science?

The teachers within the district held a slightly more reformed perspective towards the teaching and learning of science. As shown in the box and whisker plots and continuum nature of each BARSTL subscale and total score, teachers can hold contradictory beliefs that are composed of both reformed and traditional perspectives. This indicates that on average, teachers within the district held philosophies more consistent with the current reform movement in science education.

Findings from this study indicated a statistically significant difference in each subscale and total score for those teachers holding Master's degrees. Teachers who held a Master's degree scored higher when compared to those who did not. Even though a difference was observed between these two groups, the group means for all of the subscales and total score still indicated that a reformed perspective was held. Teachers who held a Master's degree did score higher, but this does not indicate that this was the sole factor contributing to the higher score or more reformed perspective. Due to the observation that both groups remained in the reformed perspective, which is the assumed goal of science education reform, it is clear that the difference might be due to other factors, related or not. These differences might be due to personality traits or existing philosophies held towards teaching and learning rather than the actual effect of a Master's program. These results do show that holding a Master's degree does have an effect on the beliefs teachers within this population held, but does not provide enough evidence to determine causation.

While the overall sample showed a more reformed perspective, it is important to look closer at each subscale and belief statements in order to understand the complexity of the beliefs held. Looking at the highest (more reformed) and lowest (more traditional) scores illuminates the differences and similarities of the teachers' beliefs within the sample. In review, statements where the teachers scored the highest indicate that their beliefs consist of student-direct learning, student-developed investigations, a teacher-as-facilitator, encouraging student collaboration, and a focus on depth of learning over breadth of content. For this sample, it is clear that statements focus around student behavior and actions within the classroom rather than on the teacher or curriculum. On the other hand, the statements that scored the lowest show traditional perspectives including a view of students as blank slates, teacher-prescribed activities, teacher-as-dispenser, and a focus on breadth of content over depth of learning. These statements focus around teachers' instructional approaches rather than their views of students.

Using the statements previously discussed, it was observed that teachers within the district hold a spectrum of beliefs that span from more reformed to traditional. Due to the BARSTL scores that were slightly more reformed and the comparison of high and low scoring statements, it is clear that participating teachers in this district do not hold cohesive beliefs about the teaching and learning of science. Even with the contradictory nature of teachers' beliefs shown in our discussion of the high and low scoring statements, a generalization can be made regarding their beliefs when looking specifically at the content of the statements. Teachers within this population believe that students are curious about science and should have the skills necessary to participate in the process of doing science within the confines of teacher-directed learning and confirmatory experiences through the scientific method. Even though the teachers hold reformed-based perspectives of their students, they still hold the belief that the best way for students to learn content is through frontal teaching and confirmatory laboratory activities that follow a fixed approach of the scientific method. This mixed belief between traditional and reformed supports the ideas set forth that beliefs are complex and not independent (Bryan, 2012). When holding a set of beliefs that are in contradiction, teachers must develop an internal structure and priority of beliefs that allows them to navigate their daily practice. It is clear that teachers within the district hold similar views composed of both traditional and reformed perspective bring to light the larger district science teaching and learning culture and idea that the district is in a period of transition.

RQ2: What is the resulting Grid and Group cultural map when using teachers' beliefs as measured by the BARSTL?

Utilizing the Grid and Group typology to plot teachers' scores as measured by the BARSTL resulted in one major cluster of teachers. This cluster was mainly located in the reformed-reformed quadrant but did have teachers who fell into the other three quadrants. Based on the placement of teachers within the typology, the establishment of four different groups could be used to further investigate the differences between each group. The larger cluster of teachers centered on the middle of the cultural map between the transition of traditional to reformed perspectives and extending towards a more reformed perspective for both Grid and Group. Due to the number of teachers who scored near the transition between traditional and reformed perspectives, the insignificant differences observed, and overall averages for several subscales extending into both perspectives, it might be helpful to propose a fifth section to the typology, *transitional*. The transitional section would center the typology and indicate that teachers who fell into this group held a combination of both traditional and reformed beliefs, either a complex web of contradictory beliefs or discernable differences in beliefs.

This statistically significant difference observed for those who held a Master's degree and those who did not, is also shown visually on the cultural map. Further, the cultural map provided visual confirmation that all but one teacher with a master's was in the reform-reformed quadrant. These teachers' scores extend towards higher reformed perspectives in both Grid and Group. Additionally, teachers who held a Master's degree fell into the reformed quadrants for grid. The grid quadrant deals with the curriculum and lesson design and implementation. On the other hand, the same group of teachers who held Master's degrees fell into both traditional and reformed quadrants for group, which deals with how people learn about science and the teaching and learning environment.

While the use of the Grid and Group typology created groups of teachers based on their beliefs, it opens more questions as to why the scores are clustered for this population. It is clear that the beliefs that teachers hold across the district are consistent, but what factors contribute to this consistency? This might be due to centralized and stable professional development offered by the district, cross grade and subject professional learning communities, state-mandated standards lending themselves to a particular philosophy, or a complex combination of factors. Additional research is needed to fully understand the factors contributing to the cluster of scores for teachers within this population.

Conclusions and Future Research

The goal of the study was to determine what secondary science teacher's beliefs were and how the application of Grid and Group theory could help categorize teachers based on their beliefs. The resulting study allowed for three major findings. First, the overall sample of teachers within the district held a more reformed perspective of the teaching and learning of science. Teachers' statement responses indicate holding more reformed perspectives concerning student actions and behaviors. More specifically, teachers agreed with statements that described students: developing skills and habits relating to doing science, challenging ideas, and bringing prior knowledge into the classroom. On the other hand, teachers agreed with statements written from the traditional perspective relating to their instructional approach. Teachers indicated that they agreed with approaches that involved teacher-directed learning, laboratory investigations focused on reinforcement of previous learning, and the use of the scientific method. While the beliefs held by the teachers within the district show a more reformed perspective of the teaching and learning of science, it is clear that teachers still hold a traditional perspective regarding some instructional approaches. The results also indicate contradictory beliefs held between teachers within the sample, thus illuminating the need to do further comparison between districts to see if similar results are found between the teachers composing other districts. This research supports findings made in the research that beliefs are on a continuum and that they are both independent of each other yet not of equal importance or influence (Bryan, 2012).

Second, teachers who held a Master's degree had higher scores on all four subgroups and total score when compared to those who did not hold a Master's degree, indicating that they held a more reformed perspective. While these differences were seen within the sample, the explorative nature of the study does not indicate that the cause of having a more reformed perspective regarding the teaching and learning of science was directly attributed to holding a Master's degree. Fives and Buehl (2012) concluded that through professional development or preservice experiences, teachers' beliefs do change depending on the targeted belief and the duration of time the teacher has held the belief while practicing. This study supports the understanding that beliefs change based on targeted experiences that teachers have before and during their career, but further research needs to be completed to fully understand the factors, within and outside the district, mediating these differences.

Third, the application of the Grid and Group typology (Douglas, 1970, 1973, 1982) on teachers' beliefs about the teaching and learning of science created one major cluster of teachers, the majority of teachers in the reformed-reformed quadrant with teachers being placed each of the four categories (traditional-traditional, traditional-reformed, reformed-traditional, and reformed-reformed). The placement of the teachers on the typology in all four categories would allow for differentiation between teachers based on their espoused beliefs. Due to the number of teachers centered on the middle of the cultural map, a proposed fifth transitional group could be formed to better describe these teachers' beliefs. Teachers within this group would hold completing beliefs composed of both traditional and reformed perspective on both Grid and Group dimensions. While two of the quadrants in the typology already illustrate conflicting beliefs, reformed-traditional and traditional-reformed, the addition of a transitional group would highlight teachers whose beliefs were balanced between traditional and reformed. Specifically, teachers within this zone could hold both traditional or reformed beliefs on both Grid or Group dimensions. This might indicate that they are in a period of transition in their beliefs, practice, or both. The transitional zone would also highlight teachers who hold beliefs that are not in one or more extreme indicating the possibility of change. This proposed fifth group, shown in figure 3.8 would modify the traditional cultural map typology as presented previously and support findings by Luft and Roehrig (2007) of a traditional zone of beliefs.   Additional research is needed to see at which point teachers' beliefs show a balance of completing beliefs, indicating a transitional stage.

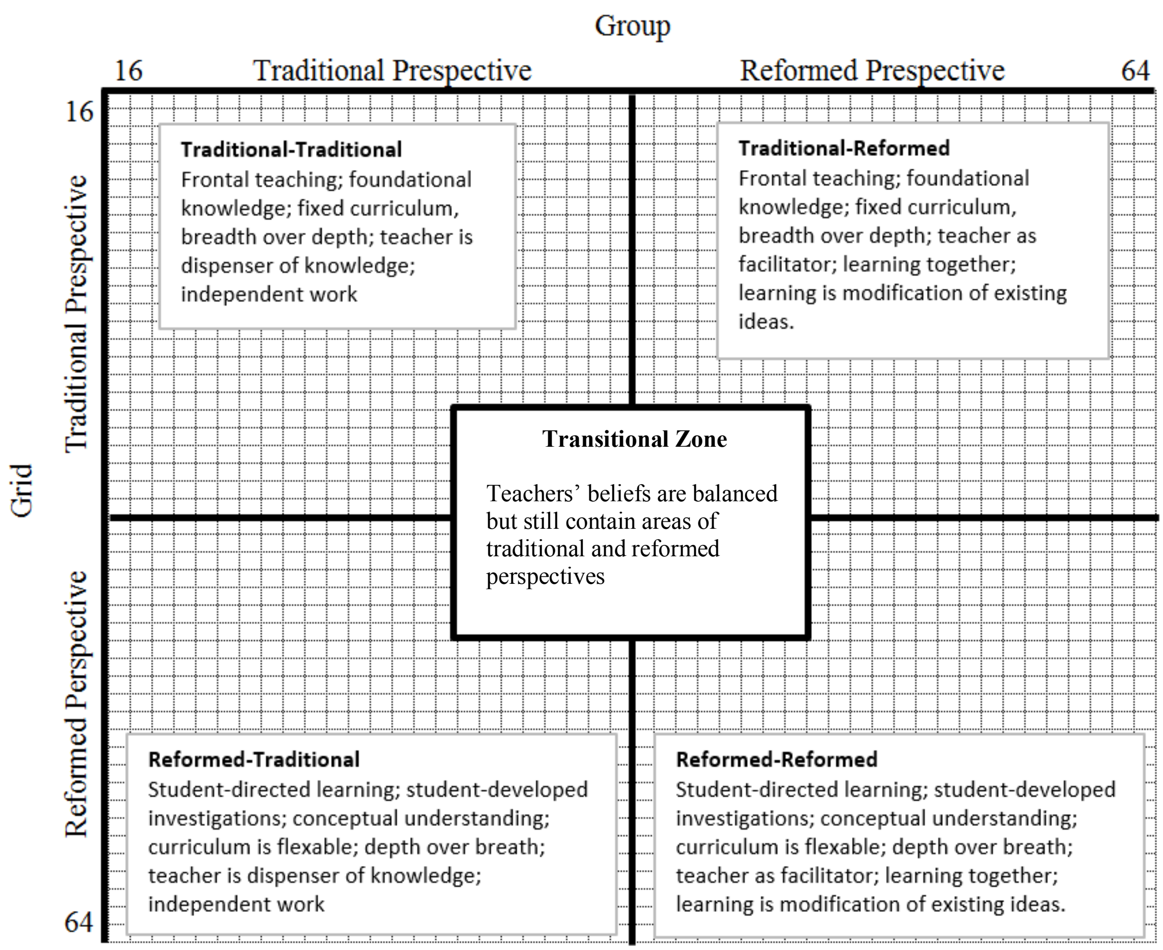

Figure 3.8. Proposed Grid and Group typology including a transitional zone of teacher beliefs.

Additionally, the cultural typology indicates that the beliefs teachers' held across the district were similar lending itself to the idea culture exists at the district-level rather than isolated at each grade-level or subject. Further investigation into the reasons for similarly held beliefs could help better understand how the district can be seen or create a culture. Performing additional research within different districts in the same local area and state, as well as different states to further support the usefulness of the Grid and Group typology to show similar results within a district and/or illustrate differences between districts.

The cultural map allows for the visualization of the difference between teachers who held a Master's and those who did not. While the beliefs teachers' held grouped teachers into each of the four categories on the cultural map, it did not clearly show differences between grade-level taught, gender, or race. However, the cultural map does allow for the development of teacher groups that could be used in follow-up studies to further investigate differences between teachers' beliefs using other methods, reasons teachers' hold these beliefs, classroom practice, and/or the relationship between these beliefs and their classroom practice. Further research in this area would help illuminate the complex and disputed relationship between beliefs and practice (Bryan, 2012; Fives & Buehl, 2012).

The conclusions from this research are accompanied by their limitations. The research explored in-service secondary science teachers from one district, thus applications to other populations should be limited until further research has been completed. Different populations of teachers might show different characteristics of beliefs resulting in different cultural maps. Additionally, the research represents self-reported data meaning that responses could represent what teachers believe the expected, or "right", answer to be. To strengthen the application of these findings, triangulation of data through classroom observations and interviews would help illuminate teacher's beliefs. The scores obtained from the BARSTL represent one snapshot of a group of teachers within one district. While overall characteristics are discussed, differences within a subgroup or between subgroups as presented on the BARSTL shows teachers holding conflicting beliefs and these beliefs might change over time with grade level, course(s) taught, future professional development, and/or experience.

As Yerrick et al. (1997) stated, teachers tend to rely on personal beliefs to guide their thinking and practice rather than following recommendations made by professional organizations and standards. This research allows for an overview of secondary science teachers beliefs that allow for visualization and grouping based on teachers' currently held beliefs. The cultural map created form the BARSTL results could allow for institutions and researchers to track change over time through professional development or implementation of curriculum. The application of Grid and Group theory allows for a view of teachers' beliefs from the perspective of a culture, and could be used to address aspects of the culture impeding the change or implementation desired. Further comparison between different populations and teacher characteristics could reveal aspects of teacher education and district culture that foster a more reform-based perspective. Nevertheless, a "considerable adaptations of teachers' beliefs in order to align their practice with the philosophy of the reform" (Sampson et al., 2013, p. 12) still must occur in order to implement the goals of the current reform movement. This research illuminates the cultural aspect of this implementation and proposes a method to visualize these beliefs on a continuum acknowledging a transitional zone of beliefs.

CHAPTER IV

STUDY 2: SECONDARY SCIENCE TEACHERS' CURRENT INSTRUCTIONAL PRACTICES: A CASE STUDY APPROACH

Targeted Journal: Electronic Journal of Science Education

Abstract

While several researchers (Buehl & Beck, 2015; Fang, 1996; Pajares, 1992) have examined the relationship between teachers' beliefs and practice, there is not one agreed upon conclusion. This study utilizes the Grid and Group (Douglas, 1970, 1973, 1982; Harris, 2006) cultural map proposed by Weinbrecht (2017) to create multiple case studies to investigate teachers' classroom practice based on their beliefs about the teaching and learning of science (Sampson et al., 2013). Utilizing a qualitative methodology, interviews and lesson plan documents were collected from ten purposefully selected secondary science teachers from a large Midwestern state school district to create five case studies. Findings from the study indicate that (a) cross-case belief regarding a focus on teaching the essentials, (b) consistency between traditional beliefs and practice but inconsistencies for reformed beliefs and practice, and (c) the support for a transitional zone. Case studies illustrate change as a process that proceeds through transition, and at times conflict, between beliefs and practice. Findings support the inconsistency perspective between beliefs and classroom practice and illustrate the complex relationship between the two constructs.

Veal, Riley Lloyd, Howell, and Peters (2016) stated that, "teachers' beliefs influence how science teachers learn reform-based strategies, how they say they teach science, and how they implement these strategies" (p. 1420). The relationship between what teachers believe, say, and do has been an ongoing line of research (Fives & Buehl, 2012) throughout the social and economic drivers of science education reform (Smith & Nadelson, 2017). Currently, research concerning the relationship between teachers' beliefs and classroom practice is on the rise (Bryan, 2012). While several researchers (Buehl & Beck, 2015; Fang, 1996; Pajares, 1992) have examined the relationship between teachers' beliefs and practice, there is not one agreed upon conclusion. Research investigating the relationship between beliefs and practice indicated that there is congruence or incongruence between the two (Bryan, 2012). Congruence is observed with teachers who hold traditional beliefs and have traditional classroom practices (Bryan, 2003), whereas incongruence is seen when teachers have more sophisticated beliefs which then do not match their practice (Dolphin & Tillotson, 2015; Savasci & Berlin, 2012; Wallace, 2014). This study seeks to investigate the relationship between secondary science teachers' beliefs and practice.

In order to explore the relationship between teachers' beliefs and classroom practice, one must first understand what a teacher believes. Sampson, Enderle, and Grooms (2013) developed and validated an instrument, the Beliefs about Reformed Science Teaching and Learning (BARSTL) (Sampson et al., 2013), which measures a science teacher's beliefs about the teaching and learning of science. Research studies utilizing the BARSTL have been used to identify and monitor changes in teachers' beliefs in varying school contexts and populations: preschool (Büyüktaskapu, 2010), elementary school (Granger et al., 2010, 2009; Khan, 2012), secondary school (Jetty, 2014), preservice teachers methods courses (Karaman & Karaman, 2013), research experiences for teachers (Golden et al., 2008), and undergraduate faculty (Czajka, 2014). This research utilized the BARSTL as a way to measure change through various professional development experiences. An underlying assumption within these studies is that a change in teachers' beliefs results in a change in classroom practice. There is a deficiency in studies supporting the relationship between the outcomes measured on the BARSTL and classroom practice, thus more research is needed to further support how the BARSTL's constructs relate to classroom practice.

This study seeks to explore the relationship between teachers' beliefs and their self-reported classroom practices by examining lesson plans and interviews about their best practice. In this study, classroom practices are defined as events, happenings, and occurrences of teaching and learning within the boundaries of the science classroom as reported by the teacher. This study seeks to describe teachers' classroom practice rather than evaluate effectiveness of classroom practice. The multiple cases, bound by belief differences observed from the application of the Grid and Group theoretical perspective proposed in Weinbrecht (2017), help to answer the following research questions: (a) what are secondary science teachers' self-reported classroom practices? and (b) how do secondary science teachers' beliefs influence their self-reported classroom practices?

Theoretical Perspective

The Theory of Planned Behavior (TPB) (Ajzen, 1985, 1991) serves as the theoretical perspective for this study because it provides a model connecting belief to action. The TPB establishes an indirect link between an individual's salient beliefs (i.e., behavior, normative, and control beliefs) and enacted behaviors. Ajzen (1991) stated that "it is these salient beliefs that are considered to be the prevailing determinants of a person's intentions and actions" (p. 189). The antecedent salient beliefs individuals hold develops the attitudes, subjective norms, and perceived behavioral control associated with a given behavior. Attitudes develop from behavioral beliefs regarding the expected outcome and subjective values towards a given outcome. Subjective norms develop from normative beliefs, an individual's belief about other influential people or group's perceptions that they should or should not perform a given behavior. Lastly, perceived behavioral control beliefs are developed from experiences, secondhand information, perceived difficulty, and other perceived factors influencing an individual's ability to perform a behavior. Figure 4.1 shows the relationships proposed in the TPB.

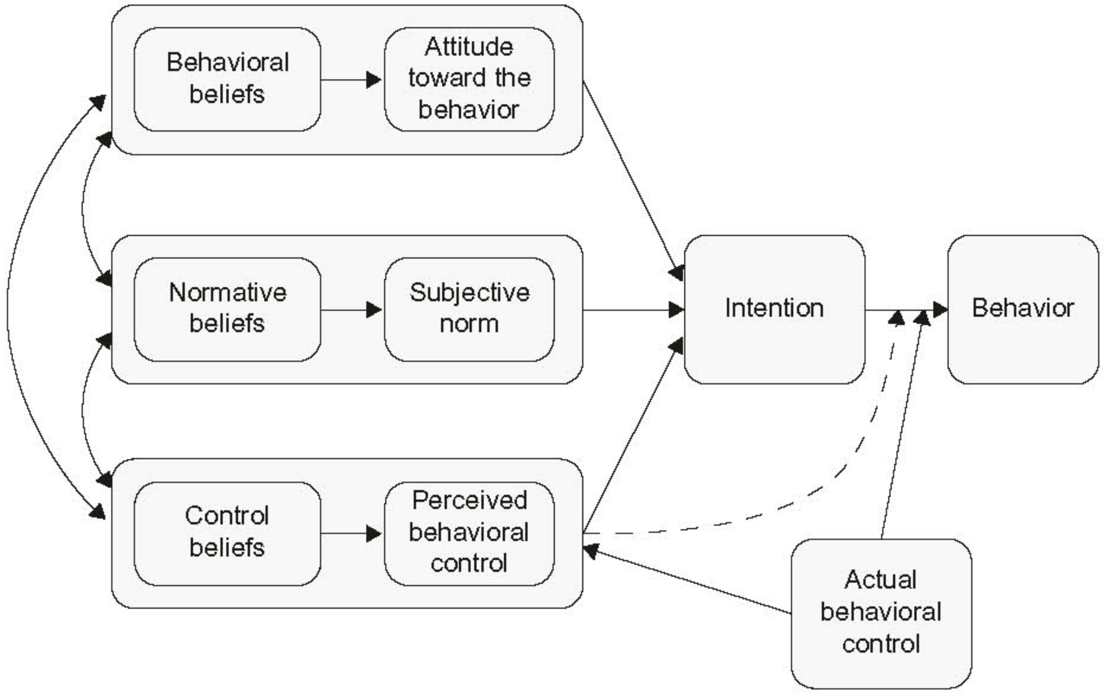

Figure 4.1. Visual representation of the Theory of Planned Behavior showing the relationships between salient beliefs and behaviors. Used from Smith, Smith, and Banilower (2014, p. 83) with permission by Springer.

The TPB acknowledges that the multi-layered explanation and importance of behavioral beliefs, subjective norms, and perceived behavioral control in predicting intention is both relative and varies given the behavior and context in which the teachers practice. The TPB has been used in several different contexts (e.g., intention to use technology in the classroom (Teo, Zhou, & Noyes, 2016), attitudes towards the intent to implement a new model of science teaching (Haney et al., 1996; Lumpe, Haney, & Czerniak, 2000), and student intention to enroll in coursework (Crawley & Black, 1992)). In this study teachers' beliefs drive the selection of bounded case studies and the resulting actions are composed of their classroom practice. The consideration of varying relevance to a behavior and context will become important as the theory is utilized to help explore the relationships existing within our context.

Review of Related Literature

Research into teachers' beliefs is extensive but not conclusive (Bryan, 2012; Fives & Buehl, 2012; Pajares, 1992; Savasci & Berlin, 2012). According to Fives and Buehl (2012) this line of research extends more than 57 years. While the line of research is extensive, with new reform initiatives emerging in science education calling for major shifts and innovations in the way science is taught, research into the relationship between teachers' beliefs and practices became paramount (Bryan, 2012). Two perspectives emerged within the research into the relationship between teachers' beliefs and practice for two separate and conflicting lines of research: the consistency or inconsistency between beliefs and classroom practice (Bryan, 2012; Fives & Buehl, 2012). Through the use of several existing instruments (e.g. Teacher Beliefs about Effective Science Teaching (questionnaire) (Smith et al., 2014), Teacher Belief Instrument (interview protocol) (Luft & Roehrig, 2007), Views of Nature of Science questionnaire (open-ended) (Lederman et al., 2002)) that focus on teachers' beliefs about science as well as methods to measure classroom practice (e.g. direct observation, self-reported, Electronic Quality of Inquiry Protocol (EQUIP) (Marshall, Smart, & Horton, 2010), and Reformed Teacher Observation Protocol (RTOP) (Sawada et al., 2002)) researchers have come to a variety of different outcomes relating to the relationship between the two constructs. Studies supporting either consistency or inconsistency between beliefs and practice range from teaching context

(Hodson, 1993; Jackson, 2011) and occupational culture (Schempp et al., 1993) to existing strongly held beliefs (Waters-Adams, 2006). The view of the relationship as either consistent or inconsistent between beliefs and practice provides the backdrop for this study.

The first line of research supports the assertion that the beliefs that teachers hold are consistent and demonstrated in their classroom practice. Empirical studies show consistent findings relating teachers' beliefs and their resulting classroom practice (Kagan, 1992). The relationship is especially evident when teachers hold traditional or empiricist beliefs about science relating to a behaviorist or transmissionist approach to teaching (Bryan, 2012; Hashweh, 1996). Jones and Carter (2007) found that the beliefs teachers held did have a significant role in shaping classroom practice, even when the relationship was not "linear or obvious" (p. 1067). In an extensive case study of a female teacher, Bryan (2003) found that her belief profile supported the assertion that "beliefs drive practice" (p. 857). Given that teachers showed coherence between beliefs and practice, Verjovsky and Waldegg (2005) found that there were difficulties integrating new or innovative ways of teaching. While these studies showed a consistent relationship, others found inconsistencies between beliefs and practice.

Inconsistency between beliefs and practice demonstrates that the relationship between espoused beliefs does not necessarily directly influence teachers' practices in the classroom (Bryan, 2012; Dolphin & Tillotson, 2015). Kang and Wallace (2005) found that teachers who held a naïve view of teaching demonstrated this in the classroom through a show-and-tell approach, but found that teachers with more sophisticated views of teaching did not show as straightforward of a connection between their beliefs and classroom practice. The inconsistency between more reformed beliefs and classroom practice might be seen because of the relationship between beliefs, teaching context, and instructional goals (Wallace & Kang, 2005). Several other researchers have found similar findings (e.g. Hodson, 1993; Savasci and Berlin, 2012; and Wallace, 2005). Teachers who embraced constructivism within their beliefs did not show this in their classroom behaviors (Savasci & Berlin, 2012). Despite the variety of findings within the research relating teachers beliefs and practice, it is important to investigate the degree to which the two align and the impacts context has on the negotiation between the two (Fives & Buehl, 2012).

The purpose of this study is to qualitatively explore secondary science teachers' self-reported classroom practices through multiple cases bounded by teachers' beliefs about the teaching and learning of science. Within each case, a rich description of self-reported classroom practice is used to examine the similarities and differences existing between their beliefs. The study seeks to identify secondary teachers' beliefs about the teaching and learning of science and explore the self-reported classroom practices associated with these beliefs.

Methodology

A constructivism worldview frames this qualitative study where reality is socially, culturally, and historically constructed to make sense of the socially enacted classroom practice of teachers as it relates to their beliefs. Through this perspective, teachers' classroom practice is influenced by their own subjective meanings of their experience, beliefs, and context (Bloomberg & Volpe, 2012; Creswell, 2013). Thus, it is important that the research design allowed for the researcher to explore the complex nature of both classroom practices and the relationship that exists between practices and beliefs. Particularly important in qualitative research, the role and perspective of the researcher as the primary data collection instrument requires acknowledgement and awareness of personal values and experiences.

This study is part of a larger study (Weinbrecht, 2018) in which an *a priori* theory was developed and evaluated to established a matrix of teachers' beliefs, based upon results of the BARSTL, which directed the selection of teachers to establish a multiple case study design (Bloomberg & Volpe, 2012; Yin, 2009). Multiple case studies allowed for the researcher to explore the similarities and differences between cases (Baxter & Jack, 2008) and to compare cases based on a theoretical framework that predicts contrasting results (Yin, 2009). The unit of analysis for this study are the five groupings of teachers observed from the application of the Grid and Group typology to the belief scores obtained from the BARSTL: reformed-reformed, reformed-traditional, traditional-reformed, reformed-reformed with master's, and reformed-reformed without a Master's degree (see initial study Weinbrecht, 2017). Each case was developed to include willing teachers, which resulted in the selection of one to four teachers per group. Institutional Review Board approval was obtained prior to data collection (see Appendix A).

Participants

The participants for the study were purposefully selected based on the results from the previous study at a large public school district in a Midwestern state. Teacher participants for this study were selected based on the following criteria: (a) currently teaching; (b) teaching assignments must contain at least one science discipline (physical, biological, and/or earth and space sciences); and (c) not employed as a substitute or emergency replacement. Participants for this study were purposefully selected from a previous study (see Weinbrecht, 2017) which grouped participants on a resulting Grid and Group matrix developed from the results of the BARSTL questionnaire (Sampson et al., 2013). The beliefs teachers held placed them into four different quadrants and showed a statistical difference between those who held a master's degree and those who did not. For this study, teachers were purposefully grouped into five groups to define the multiple case studies: traditional-traditional; traditional-reformed; reformed-traditional; reformed-reformed without a Master's degree, and reformed-reformed with a Master's degree. Of the 39 original participants, 13 indicated an interest in a follow up interview from the original study. Of the 13 participants, the following agreed and completed the follow up interview: two of three from traditional-traditional, one of one from traditional-reformed, one of one from reformed-traditional, four of six from reformed-reformed without master's, and two of two from reformed-reformed with master's. Figure 4.2 illustrates these groups, along with the belief characteristics that defined each group. Table 4.1 displays the demographic data (i.e., gender, race, grade, subject taught, experience, degree, student teaching, coursework, and certification) for the participants.

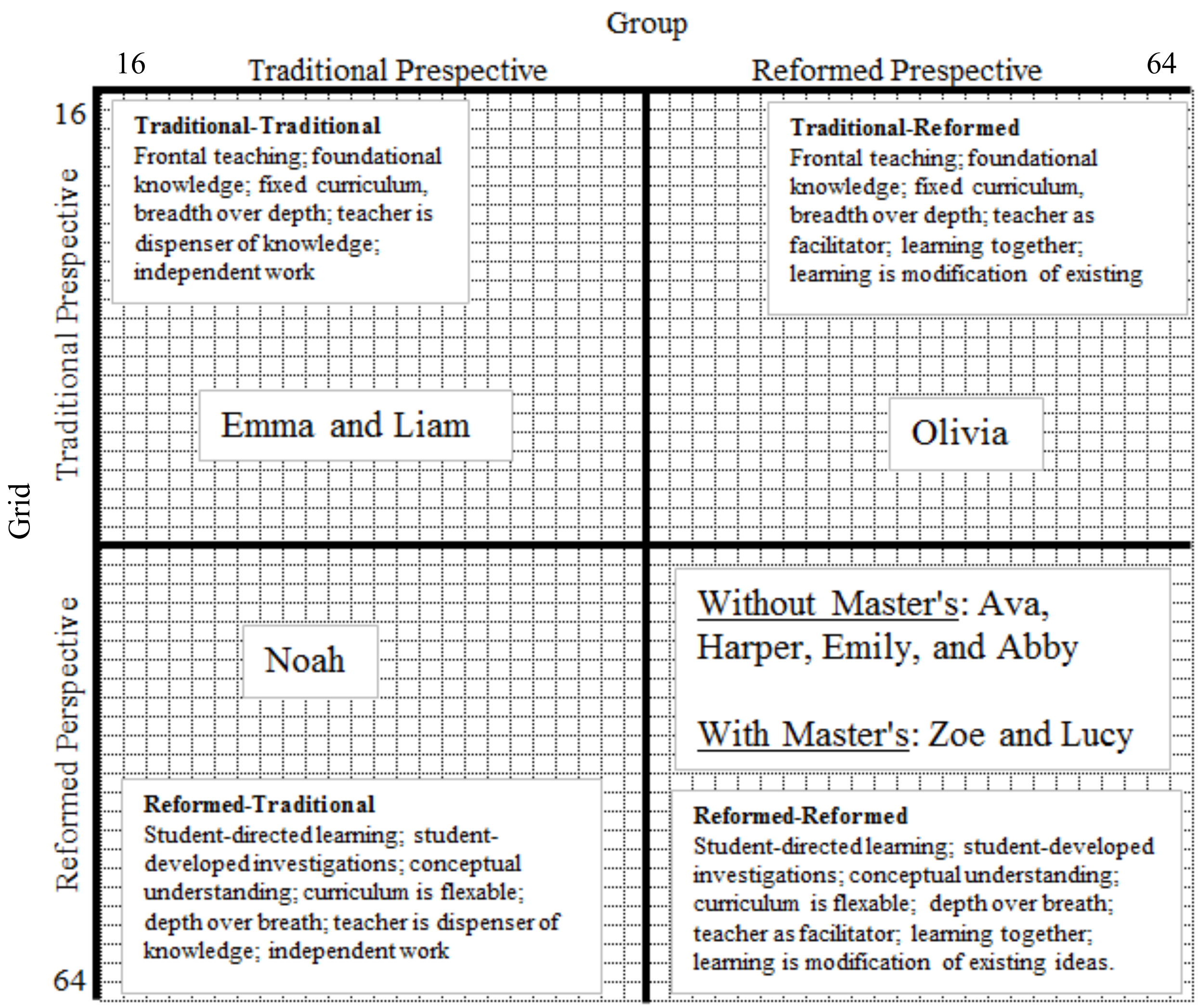

Figure 4.2. Groups of teachers based on beliefs (shown relating to how each group was defined) that established the multiple case studies used with the research.

Table 4.1
Teacher demographics for each case within the study.

Teacher	Race	Grade Taught	Subject	Years of Experience	Degree	Student teaching	Coursework	Certification
Traditional-Tradtional								
Emma (F)	White non-Hispanic	8th	General	6	Bacholor's in Elementary Education	12-Week	3-4 teaching method courses	Standard
Liam (M)	White non-Hispanic	High School	Chemistry	4	Bacholor's in Zoology	12-Week	10+ Science courses	Alternative
Traditional-Reformed								
Olivia (F)	White non-Hispanic	High School	Biology	13	Bacholor's in Biology Minor Chemistry	12-Week	10+ Science courses 3-4 teaching methods courses	Standard; National Board Certification
Reformed-Traditional								
Noah (M)	Native Hawaiian or Pacific Islander	8th	General	7	Bacholor's in Health/Physical Educaiton	12-Week	5-9 teaching methods courses 3-4 science courses	Standard
Reformed-Reformed without Master's								
Ava (F)	White non-Hispanic	6th	General	17	Bacholor's in Elementary Education	12-Week	1-2 teaching methods courses 5-9 science courses	Standard
Harper (F)	White non-Hispanic	High School	Biology and Biotechnology	18	Bacholor's in Biology	12-Week	10+ science courses 5-9 teaching methods courses	Standard; National Board Certification
Emily (F)	White non-Hispanic	8th	General	1	Bacholor's in Musical Education	12-Week	5-9 teaching methods courses	Standard
Abby (F)	American Indian non-Hispanic	8th	General	31	Bacholor's in Biology Minor in Chemistry	Semester	3-4 teaching methods courses 3-4 graduate science courses	Standard; National Board Certification
Reformed-Reformed with Master's								
Zoe (F)	American Indian; White non-Hispanic	High School	Chemistry	6	Bacholor's in Biology; Master's in Teaching, Learning, and Leadership	12-week	5-9 teaching methods courses 10+ science courses	Standard
Lucy (F)	Asian non-Hispanic	High School	Biology	10	Bacholor's in Biology and Elementary Eduation Master's in Biology	5-7 weeks	5-9 teaching methods courses 10+ graduate science courses	Standard

Data Collection

Semi-structured interviews and instructional documents (e.g. lesson plans, worksheets, and instructional videos) were collected for each case. The researcher asked selected teachers to submit instructional documents before participating in a scheduled semi-structured interview. The preferred method of data collection would have been direct observation or videotaping of classroom practice, but due to school district limitations, this was not allowed.

Instructional Documents. Prior to the semi-structured interview, teachers submitted lesson plans and instructional documents that reflected their best practice. Each teacher had the opportunity to submit any type of lesson plan or instructional documents that they identified as representing their best practice. No requirements or restrictions were provided. The researcher reviewed the submitted documents to help guide the selection and creation of follow up questions to fully understand their purpose and use within their practice. The lesson plan documents were used as a way to deepen the teacher responses during the interview process. A sample lesson plan from Liam, with corresponding follow up semi-structed interview questions is shown in Appendix F.

Semi-structured Interview. Each participating teacher completed a semi-structured interview (see Appendix D) (Bloomberg & Volpe, 2012). Interviews took place during a convenient time for the teacher that allowed for approximately one hour of dedicated time (actual interview lengths were between 25 and 75 minutes). The interview was composed of three parts: Teacher Beliefs Interview (TBI) (Luft & Roehrig, 2007), professional background, and follow-up discussion over submitted instructional documents. The use of the TBI allowed for the further exploration of our existing understandings of teachers' beliefs. The TBI is a set of seven questions that explores a teacher's beliefs about the teaching and learning of science. Luft and Roehrig (2007) validated the TBI through multiple comparisons of the data the established categories and descriptions remained consistent. Luft and Roehrig (2007) established the reliability by comparing data collected from preservice mathematics and science teachers. The types of responses were different between the two groups, supporting the reliability of use with science teachers (Luft & Roehrig, 2007). Responses are separated into five different categories: traditional, instructive, transitional, responsive, and reformed-based. These categories are discussed in further detail in the following section.

The researcher audio recorded the interviews and followed the interview protocol but asked emergent questions that developed based on the teachers' responses. The goal of the interview was to further explore the teachers' beliefs, in order to (1) provide a more thorough context of who each teacher is as a science educator, and (2) establish the teacher's intentions, goals, accomplishments, and challenges related to the submitted instructional documents. During the initial interview process, question three from the TBI was omitted by error. We contacted all participants and received correspondence from half of the participants for a follow up interview (either by phone or email) to address the omitted question and complete the TBI. All audio-recordings were transcribed and member checked by corresponding participants.

Data Analysis

Data analysis follows Yin's explanation building, where the goal of the analysis is to explore causal links between theoretical differences (2009). For this study, differences are based on teachers' beliefs. The goal in this analysis is to develop an explanation for each individual case (within-case analysis) in order to then draw comparisons between cases (cross-case analysis) (Bloomberg & Volpe, 2012). The explanation building process involves a series of iterations of the following: (a) making an initial theoretical statement regarding a case, (b) comparing findings from the case to initial theoretical statement, (c) revising statement as needed, (d) comparing findings of case to revised statement, and (e) comparing revised theoretical statement to that of other cases (Yin, 2009).

For this study, an explanation building technique was used after the interviews, instructional documents, and TBI (Luft & Roehrig, 2007) responses were analyzed independently for each teacher. Using this method, a layering technique of emergent themes from each data source, all data from one teacher, and all data within the group was analyzed to develop an overall case description (Yin, 2009). Development of between case comparisons occurred through descriptive framework and the explanation building process. This analysis technique allowed for the development of a descriptive framework that fully describes each case so that the development of comparisons between cases were made through the explanation building process (Yin, 2009). The sections that follow represent the data analysis techniques used for each data set collected.

Semi-Structured Interview and Instructional Documents. Once data collection and transcription was completed, each teacher's responses was analyzed in its entirety. This data was analyzed with the corresponding instructional documents so that unclear responses provided by the teacher could be referenced to the instructional documents that they were referring to. It was not the goal of the analysis to evaluate the instructional documents but rather to use them as a framework for what a teacher described as their best practice. During this initial read, the focus was on getting a sense of the entire collection of data. Once this was completed, open coding for all the data occurred. During open coding, the goal was to develop as many possible codes without considering how each code relates to another (Emerson, Fretz, & Shaw, 2011). After open coding was completed, data bits were extracted and placed on cards. Data bits represented participant words that illustrated codes developed during open coding. From these codes, emergent themes developed by sorting and resorting cards. During the development of emergent themes, priority was given to the member's meaning, what they thought was significant, key, or particularly important (Emerson et al., 2011). After creating themes, focused coding allowed for comparisons, variation, and relationships among the data to be established. This allowed the emergent themes to be broken down into subthemes so that each part created a thorough description of the teachers as shown in the interview data and instructional documents.

Teacher Beliefs Interview. After initial coding of all interview and instructional document data, analysis of the TBI followed the protocol established by Luft and Roehrig (2007) and summarized here. The TBI is composed of seven questions that seek to explore the beliefs that teachers hold regarding the teaching and learning of science. Two researchers independently coded each question, making note of codes that supported the various beliefs the teachers held. Establishment of interrater agreement (93% agreement) occurred through several rounds of comparing and discussing codes. Placement of codes on a continuum indicates the category or level of beliefs held: traditional, instructive, transitional, responsive, and reform-based. Each question had a corresponding description that describes each level (shown in Appendix E). A traditional level represents teacher-centered beliefs with the view of "science as based on facts, rules, and methods that are transferable" (Luft & Roehrig, 2007, p. 43). The instructive level also includes teacher-centered beliefs but includes a belief that allows student experiences to start driving learning. A transitional level takes a view of students not centered on cognitive involvement but rather on the behaviorist and affective attributes. A transitional level views “science as a body of certain knowledge” (Luft & Roehrig, 2007, p. 43). Both responsive and reform-based levels refer to student-centered beliefs, where reform-based views “science as a dynamic field that is subject to revision” (Luft & Roehrig, 2007, p. 43) whereas responsive only refers to development of knowledge. The levels used to score each question are summarized in Table 4.2. After scoring each question and reaching agreement, the beliefs are displayed in a profile table that summarizes all beliefs captured throughout the interview. The belief profile can be used to look at changes over time or differences among teachers (see Luft & Roehrig, 2007).

Table 4.2

Teacher Beliefs Interview Category Descriptions

Category	Example	View of Science
Traditional: Focus on information, transmission, structure, or scources	I am an all knowledge sage. My role is to deliver information.	
Instructive: Focus on providing experiences, teacher-focus, or teacher decision.	I want to maintain a student focus to minimize disruptions. I want to provide students with experiences in laboratory science (no elaboration).	Science as rule or fact.
Transitional: Focus on teacher/student relationships, subjective decisions, or affective responces.	I want a good rapport with my students, so I do what they like in science I am responsible to guide students in their development of understanding and process skills.	Science as consistent, connected and objective.
Responsive: Focus on collaboration, feedback, or knowledge development.	I want to set up my classroom so that students can take charge of their own learning.	
Reform-based: Focus on mediating student knowledge or interactions.	My role is to provide students with experiences in science which allows me to understand their knowledge and how they are making sense of science. My instruction needs to be modified accordingly so that students understand key concepts in science.	Science as a dynamic structure in a social and cultural context.

Used from Luft and Roehrig (2007) with permission by Electronic Journal of Science Education.

Results

The results of the study are broken down into two sections: Teacher Belief Interview and multiple case study descriptions. The Teacher Belief Interview data was used to further support the findings and cases established from the initial study (Weinbrecht, 2017). The second section provides the results that emerged from the interview and lesson plans presented case by case.

Teacher Belief Interview

The results of the Teacher Belief Interview (TBI) are shown in Table 4.3. Each cases was bounded by the results obtained from a previous study (Weinbrecht, 2018) and grouped according to their placment within the Grid and Group typology: traditional-traditional, traditional-reformed, reformed-traditional, and reformed-reformed. The traditional-traditional case held the majority of their beliefs in the traditional or instructive category as measured by the TBI rubric (see Appendix E) supporting their placement in the traditional-traditional case. Both the traditional-reformed and reformed-traditional groups demonstrated beliefs between traditional and responsive again justifying their placement within a transitional and/or conflicting belief zone. The reformed-reformed cases both demonstrated beliefs that moved toward reform-based but still had several that scored in the traditional or instructive category. The results support our original groupings, or cases, of teachers shown in Figure 4.2 by supporting the differences between the groups based on their beliefs. Results obtained from the Teacher Belief Interview that related specifically to classroom practice were coded and included in the case analysis. The discussion of what a teacher believes opened the door for more in depth discussion of their classroom practice through follow up questions and lesson plan analysis. The following section presents each case and the themes and data sources composing each case.

Table 4.3

Beliefs profile for teachers as measured by the Teacher Beliefs Interview

Teacher	Traditional	Instructive	Transitional	Responsive	Reform-based
Traditional-Tradtional					
Emma	Q4; Q5; Q6	Q2; Q3; Q7	Q1		
Liam	Q4	Q2; Q3; Q5; Q7	Q1; Q6		
Traditional-Reformed					
Olivia	Q4; Q5	Q2; Q7	Q1;Q3	Q6	
Reformed-Traditional					
Noah*	Q5	Q4	Q6; Q7	Q1; Q2	
Reformed-Reformed without Master's					
Ava		Q1; Q2; Q3; Q4; Q6	Q5; Q7		
Harper*		Q4	Q6	Q1; Q2; Q3; Q5; Q7	
Emily*	Q1; Q5	Q2; Q4; Q7	Q1; Q6		
Abby*	Q4		Q1; Q6; Q7	Q2; Q5	
Reformed-Reformed with Master's					
Zoe*	Q5	Q4	Q1	Q2; Q6; Q7	
Lucy*		Q4; Q6	Q1	Q2; Q5; Q7	

* Indicates that question three was omitted from interview even after follow up correspondence.

Multiple Case Studies

Traditional-Traditional Case. The first case was composed of two teachers, Emma and Liam, who represented beliefs categorized as Traditional-Traditional. These teachers' scores from the initial study (Weinbrecht, 2018) indicated that their beliefs promoted: frontal teaching, foundational knowledge, a fixed curriculum, breadth over depth, teacher as dispenser of knowledge, and independent student work. This case was characterized by classroom practice that consisted of a busy environment that was led by a teacher-delivered content. The activity of the teacher focused on confirmatory science labs and skills to master the scientific method. The most learning occurred when there was a good relationship between teacher and student, but the teachers did hold negative views on their students' ability to master the content. The results from this case support the idea that the teacher's beliefs used to develop the case and TBI are consistent with their self-reported classroom practice. The following presents the themes within this case.

Busy by Doing. The classroom activity is busy with tasks. Some activities are independent whereas others focus on group work. "I try not to have too much dead time" (Emma). The teacher has "something ready for them when they walk in the door" (Emma) and "we might [do] 15 minutes of lecture, 15 minutes or 20 minutes of practice problems" (Liam). Both describe the goal of "keeping them on their toes…keeping them always doing something" (Emma) through out the class period. "I try to keep them awake" (Emma) and "on track" (Liam).

*Dispenser/Receiver Relationship***.** The focus of the classroom is on the teacher delivering the information and the students receiving the information. Liam describes preparing for the next unit by "I read the whole chapter and make notes." Emma says that "I walk around the room and make sure I'm moving, and they're tracking me because it is so boring to stand up in front of someone if I'm doing notes. I ask myself, do I need to stop at any point in the slides and break up the boring notes stuff?" In addition to notes, each teacher described instructional strategies that they use in the classroom: creating pictures for vocabulary words, copying interesting facts from presentations, teaching relevance of content, and repetition of material. "I believe that you can't just say it once and expect them to know it. You have to say it, and do it, and have them do it and come from every angle" (Liam). Emma goes further and says that "repetition is a big part of what I do…I literally repeat myself over and over and over." Students are described as "parrots" because they repeat what is said by the teacher.

Essentials. The content presented in class centers around the essential and factual knowledge and basic skills that are determined by the teacher, department, or resources (e.g., textbook and internet). The content in the class is determined because they are "under a time restraint to get everything taught for the test" (Emma). Emma also says that her teaching centers around giving "lots of graphing" so that they have this skill mastered on the test. Each lesson submitted by the teachers within this case focused on basic skills around literacy and research skills, and were described as one of the best lessons of the year. Emma planned her lesson because it "encompasses literacy" whereas Liam planned the lesson "because of the students' lower reading and writing ability."

*Scientific Method and Demo Labs***.** The teachers focused on using the lock-step, linear scientific method as the driving force of lab work. Emma stated that "the scientific method, which is, to me, the umbrella of all of it." She described her teaching as providing the content to the students and then to bring in as much "critical thinking skills of the scientific method" as possible (Emma). In conjunction with the scientific method, both teachers focus on labs that they are able to show and explain what is happening to the students. Liam describes what he calls his lower level environmental students in lab, “it’s a bit different here I will have them doing an activity or lab and I will be explaining it to them as they go along.” Talking about the provided lesson, Emma was proud of her “amazing” lab when she “dragged their desks to show them friction with them in it” and stations that students could perform a task to see Newton’s Three Laws of Motion. Overall, these teachers rely on labs and activities that are based in the lock-step, linear scientific method or demonstration labs with little student-driven portions.

Communication and Rapport Drives Ability to Learn. The teachers focus on the relationship they have with their students because to them, this is what drives the learning. If the students do not feel comfortable, they will not learn. “I’ve been about to figure out better ways to communicate with them, not only that I care about them, which I truly think is the ingredient to being successful” (Emma). Emma goes on to say that she is happy with the improvement she has experienced with students over the years she has been teaching. The success Emma has observed she attributed to the emotional connection and communication with students, “you cannot get away from the emotional component of the job” (Emma). Liam also describes his belief of the personal component of the job and states that “I want my students to appreciate me and to feel comfortable around me because I feel that’s the best way to make them learn.” Asking him how he achieves this, he said that it is “something I say a lot in class, ‘Hey, I believe in you’” (Liam). With a laugh, Liam said that it is always followed by a class eye roll.

Limited View of Students’ Ability. Lower level students in the class do not have the ability to do the “higher-level” students’ labs. Rather the teachers focus on more hands-on activities that they consider appropriate for these students. “My environmental science students, who are a little bit lower functioning, I find more hands on compared to my higher functioning chemistry students" (Liam). Emma describes teaching "lower level" students saying "then you show a video…in a very lower level." Liam summarizes the perceived issue by saying, "I try to challenge them but if I challenge them too much, then they will shut down on me." The teachers in this group have a limited view of students' ability and structure the classroom instruction so that it is at a "lower level."

Traditional-Reformed Case. The second case was composed of one teacher, Olivia, whose beliefs are categorized as Traditional-Reformed. The beliefs that this teacher holds includes the following: frontal teaching, foundational knowledge, a fixed curriculum, breadth over depth, teacher as facilitator, learning together, and learning as modification of existing ideas. The classroom practice that was present in this case included a heavy focus on getting through the content to master the objective set by the College Board. Laboratories were guided at first with a gradual release to student-developed. Her role in the classroom was to be the facilitator and to challenge the students thinking as it moved towards the correct model. While the beliefs presented by the teacher within this case have areas of conflict, the classroom practices shown match that presented in the BARSTL and TBI. Both the beliefs and classroom practice show a complex integration of both more traditional and reformed perspectives. The following presents the themes within this case.

Content and Calendar Driven. The classroom pace is driven by both the amount of content that needs to be covered and the calendar. "The calendar is pretty much set in stone" (Olivia). The content in her class is driven by the College Board (she teaches Advanced Placement classes), and she "looks at that test scores and the feedback I get over the summer and kinda tweak my calendar" (Olivia). When talking about her assessments in class, Olivia stated "I try to vary assessments quite a bit. Real standard quizzes or tests. I told my classes today, quiz Friday and chapter 4 exam Tuesday." Along with classroom drive determined by amount of content and the set calendar, she also said that "I kind of take pride in knowing when to really stress them out and when to kind of have fun…I tend to be the one that walks the fine line between challenging them and knowing when to let up" (Olivia). Here, Olivia describes the rapid pace within her classroom and acknowledges that it might be rushed but meets her need to follow her set calendar.

Teacher as Lab Facilitator. During a lab or activity, the teacher focuses on being a facilitator. During this time, she is helping as needed. "I like to be just the facilitator, where they're doing the work and I'm just kind of moving around and helping when I need to be" (Olivia). When asked to describe why she teaches this way, she stated "I don't know how you teach science without doing labs, and activities, and hands on stuff.' Throughout the year, Olivia builds towards full inquiry labs in class, "by March or April is when they do their first full blown inquiry. They decide the problem, they decided the procedure, and I just kind of help if they need guidance." She did acknowledge the challenge of getting students invested in "full blown inquiry." "They don't want to do the hands on activities. They want to be passive, look stuff up in the book and fill out a worksheet" (Olivia).

Student Collaboration. There is a focus on group work in the classroom. The teacher knows that the students learn best when they work together on labs and activities, "I think they learn best in groups" (Olivia). She further describes student collaboration during labs by "they are trying to explain to each other what's going on. One person is collecting data; one person is calculating what the data means" (Olivia). There are still times of teacher-provided lecture, but the majority of the time is given to labs and activities. When discussing her lesson plan that she submitted, she emphasizes student collaboration though a closure activity that requires students to work together to summarize their learning on genetic factors relating to cancer, “they’ve gotta do for me is write a sentence that summarizes several factors in how that’s leading to cancer” (Olivia).

Learning through Modification and Accumulation. Addressing prior knowledge and changing understanding occurs through discussion, collaboration, and assessment. Oliva expects that students understand previously covered topics by reviewing these topics in a warmup, “students reviewed previous content by completing a diagram of the cell cycle” (Olivia). The objective of the lesson she submitted was to “describe how our current understanding of cancer can explain the role that each factor plays in causing cancer” (Olivia). Over the course of the lessons, Olivia expected that students continue to add more and more knowledge with little to no time to revise and integrate new pieces of information.

Reformed-Traditional Case. The third case was composed of one teacher, Noah, whose beliefs are categorized as Reformed-Traditional. The beliefs that this teacher holds includes the following: student-directed learning, student-developed investigations, conceptual understanding, curriculum is flexible, depth over breath, teacher is dispenser of knowledge, and independent student work. Classroom practice characteristics of this case include curriculum driven agendas that allow for student input and questions. Students engage in laboratory activities that were self-directed were the teacher was hands off. For this case, the beliefs held represented those who might be in conflict but the belief statements may match that of the classroom practice. While both beliefs and practices were more reformed, there are elements of traditional practice as he describes being curriculum driven and hands off. It is important to note that this case displays a unique situation that illustrates the complex integration of contradictory beliefs and the resulting classroom practice. Specifically, the teacher describes their practice as being directed by the student at the same time as the curriculum and labs include student choice only within the bounds he established. The following presents the themes within this case.

Curriculum Drives, But Does Not Dictate. The teacher focuses on the scope and sequence of the course that is established by the state standards and district sequence. Noah stated that "I teach everything that they ask me to teach." He follows this statement by clarifying, "we have a rough outline of everything, um, it fluctuates" (Noah). While the curriculum covered in class is directed by outside factors, Noah believes that student interest is important and allows their interest to drive the focus of a lesson or unit. "I like to let them kind of dictate where the lesson goes" (Noah). He was insistent that he covers the required material, but stated if "we have a few weeks here and a few weeks there so we can go in and explore what they're curious about," he would (Noah).

Student-directed Learning. Students are empowered to direct their own learning and set goals for themselves. Students are not force fed the content; rather, they work at their own pace and get feedback from their questions and discussions. Noah expressed a concern, "we have to say we need to teach this and we need to teach that to stay at level…but I always fear of missing a step with a kid or kids and feel like forcing them to go through stuff rather than letting them go through on their own" (Noah). In this class, there is a balance between covering the required material while still allowing students to have interest and venturing out on their own learning adventures. He goes on to state, “I like to let the kids go on their own” (Noah). Student-directed learning occurs through discussion and student questions regarding the topics. “I feel like that’s how a lot of learning takes place is through discussion” (Noah).

Build a Foundation. The content and assessments of the class focuses on the basic foundational knowledge. Noah expressed that he “scaffolds the information to where my lower kids all start at the same spot as everybody, but everybody has a chance to get work to a higher level” (Noah). While the course focuses on foundational knowledge, there are student-directed opportunities for higher level content. Noah describes the process of ensuring that his students have mastered the foundational content by stating “every Friday I give a small just quick 5 questions that I think these are the five or six important things that they need to understand. When the majority of the class is understanding to where I can move on and pull a small group, the few kids for intervention.” The class is structured so that every student has the opportunity to learn and master the foundational content before the teacher moves on to different content.

*Student-directed Labs within Guidelines***.** Labs are structured so that there is freedom for student directed questions, procedures, and data collection. Guidelines are provided to help steer them in the correct direction. Noah described his lesson plan where students worked with Newton’s Third Law of Motion by building rocket-powered racing cars. Students were required to develop their own design, test the rockets in a race, and revise design for better performance. Noah stated, “I’ll let them determine what it is they’re testing and how they’re going to test it…We go back and discuss what worked and why. Then I allow students to make adjustments to cards as necessary.” The labs are structured so that the students are doing the majority of the thinking because Noah makes the labs “as vague as you can leave the lab and have the students fill in a lot of the stuff." He did express concern regarding this type of lab, "some kids get frustrated with the vagueness and so you want to fill in as much as possible because I don't want them to be frustrated, but I like them to create the question" (Noah). While the labs are not fully student-developed, the structure of the class allows for student discovery and reflection within the boundaries of the lab.

Hands-Off Facilitator. The teacher focuses on student-directed learning and labs through a hands-off approach. "I just kind of sit back and watch and kind of make sure that they're following in the lines…and it's actual science that they're coming up with" (Noah). During student-directed times, he described his role as "I'm walking thorough the lab groups and kind of just asking small questions, I can see everyone's engaged" (Noah).

Reformed-Reformed Case. The fourth case was composed of four teachers, Ava, Harper, Emily, and Abby, that represented beliefs categorized as Reformed-Reformed but did not hold a Master's degree. The beliefs that these teachers hold are as followed: student-directed learning, student-developed investigations, conceptual understanding, curriculum is flexible, depth over breath, teacher as facilitator, learning together, and learning is modification of existing ideas. The classroom practice that was described in this case presented, at times, as contradictory. A major thread was that lecture was still a must for students to learn content, but was supported by the laboratories done in class. The teachers described their role as a manager focusing on ensuring work was getting completed. Some teachers felt that the learning that occurred in their classroom was focused on depth of content whereas others felt they needed to cover content and move on. Overall, these classrooms were described by the teachers' as student focused with teachers still maintaining the control over content. When relating the beliefs that frame this case to that of the classroom practice, contradictions between the two occurred. The classroom practice reported here shows a complex mixture of more traditional or reformed perspectives. The following presents the themes within this case.

"I" Direct Content: Lecture is still a must. Each teacher expressed that lecture and teacher provided content delivery is still a must in the classroom. Harper admitted, "I'm a little bit of a control freak which is kinda necessary. At the front of the room, I just haven't given up enough of my control. I still think I drive the content." Emily describes how she runs her classroom by stating, "I try to minimize my talking as much as possible…which of course is impossible to do completely…so I still have lectures and stuff." Emily continued her discussion regarding lectures in her class by referencing a phrase she tells her students, "Don't you think it would be a good idea to, like, copy the notes down?" Ava acknowledges that she finds it still appropriate to stand in front of the class and teach. While the teachers create a learning environment that is directed by themselves, they still consider the interests and knowledge that the students bring into the classroom. "I start figuring out the misconceptions" (Ava). Harper asks herself the following question when developing her lecture, "Here's my destination. Now if this is where I want them to be, how am I gonna get there?"

Depth through application vs. Simplify content and move forward. There were two different philosophies regarding the use of content in the classroom. One group felt that content should be put to use through application, whereas others viewed it as a driving force for mastery through assessments. Supporting the first group, Ava discussed that she is provided freedom to cover the material that she feels is important for the students and spends time to apply the knowledge (e.g. building a roller coaster). Harper stated, "I have a big picture of the big concepts I want them to come away with, one topic is interwoven into the next." Content is used in practical applications by completing an end of the year project that integrates all of the material they have learned. On the other hand, other teachers felt that content should be made as simple as possible; the teacher covers it, and then moves on. Emily stated, "We've spent two weeks on this and if you don't know it yet, too bad." Abby described her planning by saying "it's always good every year to rewrite [the objectives] in my lesson plan book." Ava focused her discussion on content by stating, "I do try to get through all the standards." Finally, Emily discussed struggles that she had with students and the curriculum, "I would simplify it more because it was confusing. The curriculum is kind of like entertainment, but they don't care and listen."

Group learning for Investment and Interest. Students work in groups so that they are invested and interested in the learning happening in the classroom. Teachers acknowledged that learning does not occur in isolation and promote collaboration (in various formats) between students. "We have to do collaboration between students, get them invested in their learning" (Abby). Ava discusses the balance between lecture, discussion, and interest, "I'm good at lecturing…I'm good at class discussion…but it's not necessarily what's good for them, they learn best when they are involved." Ava shared that her classroom focuses around student group work so that kids have responsibility with their own learning. When deciding what to do in class, Harper stated "sometimes it's about what's interesting. I'm getting read to go do a GMO lab" and Abby says that she tries to "find something that will get the kids interested."

Manager. Teachers expressed that their role in the classroom was as "Manager" rather than facilitator. "I'm supposed to lead them in a direction/especially in the lab more than anywhere else I become a manager" (Harper). This consisted of guiding/directing students, questioning, and "walking around". Abby explained that students in her class are working in groups and her job is to create an environment where the kids have what they need and she is managing questions, resources, and direction. Ava believes that "you got to be on your feet" and that her presence causes the students to learn. She manages by "walking around" and "asking questions, making sure that they are doing what they're supposed to be doing" (Ava).

Models and Activities. Teacher developed models and activities drive what happens in the classroom. Students are involved in these as activities during instruction. Students "learn best through activities where they can be actually touching things" (Emily). Harper discussed labs at the start of the year were the students focused on understanding different procedures specific to the discipline. Additionally, students are engaged in computer simulations when the science is not accessible due to budget or scale (e.g. Harper discussed a DNA sequencing computer simulation). Lastly, students create scale models of things that they are learning in class (e.g. Emily had the students create candy models of the Earth to explore the layers).

Labs vs "Labs". There were two different understandings of what constituted a lab. All teachers had students engage in what they called a lab, but only one truly described student-driven lab work through the scientific practices. Others described activities they made into labs by added a graph, touching equipment, or writing analogies. Emily described a lab in her classroom by saying that it is "one big lab activity that has a bunch of steps and different things that they're doing." Ava discussed a lab where she asked the students "to pick up and handle the glass beakers" and then write an analogy to describe the state of matter in the beaker. Emily proudly said that "I've edited lots of their activities so that somehow there's a graph on there.

Even though it was originally just a regular activity, they did it as a lab somehow." On the other hand, Harper describes the end of her year by saying that "they're loading the dishwasher themselves, they're making their own solutions. They're making their own gels. All the stuff you would expect them to do in the workforce." Labs are structured so that "they get to design their own lab" and "Everybody publishes their data at the front of the room and we all talk about it" (Harper). The process that the students engaged in creates a year's worth of investment in the scientific process. Overall, there is a variety of different ways that labs are performed in the teacher's classes.

Reformed-Reformed Master's Case. The fifth case was composed of two teachers, Zoe and Lucy, what represented beliefs categorized as Reformed-Reformed who held a Master's degree. The beliefs that these teachers hold are as followed: student-directed learning, student-developed investigations, conceptual understanding, curriculum is flexible, depth over breath, teacher as facilitator, learning together, and learning is modification of existing ideas. The classroom practice that was described in this case closely matched the beliefs that they held. Students are engaged in laboratory experiences that support their learning with a focus on conceptual understanding and application. The role of the teachers in these classrooms was as facilitator where the process of learning was valued and student input helped drive the curriculum. Looking at the relationship between the beliefs and classroom practices held for this case show areas that are consistent, as described, but also aspects that demonstrate a traditional perspective. Specifically, the understanding of laboratory work demonstrates a mix of in depth application of concepts while holding the idea that laboratories are "experiences" for the students overlooking the larger purpose in science teaching and learning. The following presents the themes within this case.

Experiences through laboratories. Both teachers focus their work in the classroom around lab work. Lucy described her students' reactions to the various labs they did in class by say, "the kids really liked the labs. 'Oh my gosh! My bag is heating up!'". Their excitement came across when discussing both of the submitted lesson plans stating, "anytime it can be lab-based or lab-oriented, whether as inquiries or more like a guided inquiry" (Zoe). The teachers focus the lab work around investigations that allow students to experience and participate in data collection and interpretations. Each described the labs done in class as consisting of "coming up with procedures, do the testing and giving them a little bit of time to think about what they are going to write" (Zoe). During labs students might not "necessarily see it occurring, [but] it is occurring, it is a tangible product" (Lucy). Lucy describes a lab experience where they are using photosynthesis Legos, "a great way to bring it more to life and it was something tactile and they can move." While the teachers described students conducting and experiencing labs in class, it should be highlighted that their understanding of true student-centered and student-developed labs was missing, rather the focus was on lab only as an experience rather than an opportunity to build knowledge.

Conceptual and Application of Content. The use of content in the classroom is based on conceptual understanding where they are expected to apply the ideas to varying contexts. The goal of instruction is not solely to have kids memorize material, but rather "synthesize all of the information that they've been given to show some kind of end product" (Zoe). Both teachers described instruction where students were engaging in problem solving or "lab-based study" (Zoe) so that "they've processed it and are applying it into different areas" (Lucy). Additionally, each discussed the idea that students can know the periodic table, but the goal in their classroom was for students to know "all the different ways they could use the periodic table" (Zoe). It is evident that content in the classroom lays the foundation for further conceptual development and ultimately the application of new learning.

Student Choice. The structure of the classroom does not include student-directed learning, rather the teacher provides all students choice in their learning. Lucy expressed that "I hate to teach to the test" and she was "not trying to shove it down their throats." This was accomplished by allowing the students to "work on their own, at their own pace" (Lucy). Zoe used a more structured method for student choice, "I found it to be really helpful…I started using the menu system. It was like a tic-tac-toe board and the students could pick which types of lessons they wanted to do." The students had options when covering a topic in her class. This "gave them motivation to actually do something, they had a choice" (Zoe). Zoe also discussed that with this instructional decision to provide student choice came an instructional struggle "a lot of it is me just watching them fail, and there's a lot of failing." Lucy described the same struggle regarding students working at their own pace. She wanted the students to use their resources and gain confidence in finding the answers themselves, but students become frustrated with her. Lucy refused to provide the answers; rather, she provides resources, materials, and guidance towards the correct understanding.

Learning is valued over answers. For the teachers within this group, the learning process is central to the classroom. The teachers create an environment where "Everyone is given the same experience first, so we all have the same jumping off point" (Lucy). Both teachers expressed the desire to meet the students where they were in their own understandings. Lucy referred to providing "as much background as possible," whereas Zoe will "post all of the answers up on the board for reference". This allows for the creation of a classroom were each student has the same opportunity to develop in depth understandings of the content. Assessments are formative and do not focus around the expected answer, rather what learning has occurred and what still needs to occur. The teachers create an environment were learning is the focus over students providing answers.

Facilitator with student collaboration. The classroom is setup so that students are expected to collaborate with each other and the teacher acts as a facilitator of student choice, investigations, and learning. Both teachers described their roles in the classroom as a facilitator. Unlike other groups who used the word without effectively describing classroom practice that lends itself to facilitation, Zoe stated, “I know people like to throw around the word facilitator, but I really, really am a facilitator.” Zoe went on to laugh and say, “I think there’s two times out of the whole entire school year that I actually stand up and present material.” Through their role of facilitating the classroom, Lucy expanded her description of her role by saying “a lot of my role as a teacher was not just for content, but was definitely to get them ready to be productive citizens.” It is evident through the classroom practices described previously by these teachers; both Lucy and Zoe hold characteristics of being a facilitator in the classroom.

Discussion and Conclusions

The purpose of this study was to explore secondary science teachers’ classroom practices through multiple case studies bounded by teachers’ beliefs about the teaching and learning of science. The study sought to explore the relationship between teachers’ beliefs and their self-reported classroom practices by examining lesson plans and interviewing teachers about their beliefs and best practice. The results are discussed utilizing the Theory of Planned Behavior (Ajzen, 1985, 1991, 2012) as our theoretical framework to help understand the relationship between beliefs and self-reported classroom practice. The results of this study support the development of three conclusions: (a) cross-case belief regarding a focus on science content essentials, (b) consistency between traditional beliefs and practice but inconsistencies for reformed beliefs and practice, and (c) the support for a transitional zone.

Cross-Case Beliefs

The teachers within the cases discussed their belief that students should master skills they deemed essential and defined by their department and the district. Even though teachers in each case discussed skill viewed as essential, their interpretation and implementation varied. For teachers in the traditional-traditional case, it drove their decisions and selection of topics to teach. This also seemed to become a limiting factor for the traditional-traditional teachers as they discussed that their students would only be able to master these foundational essential skills and would not be able to master more complicated or sophisticated concepts. Focusing on essentials and foundational knowledge with the belief that only some students can and will achieve at higher levels adds to ideas Bryan (2012) presented while discussing the consistency between beliefs and practice. On the other hand, teachers who held some or all reformed beliefs discussed the need to teach essential skills as a foundation that would then be used to further explore and expand their students scientific thinking. The essential skills were one part of the larger picture of the instruction and teaching that occurred within the classroom. This supports Verjovsky and Waldegg (2005) case study which described a secondary teacher having an intentional focus on reformed practice allowing her to meet the expectations of others while still teaching in a way that matched her beliefs. A commonly held belief across each case seems to have different effects on teachers depending on the beliefs that they personally hold about the teaching and learning of science. The effect of normative beliefs and subjective norms (Ajzen, 1985) on teachers' intentions and actions is shown throughout all cases because teachers express a common need to teach essential skills advocated by influential people, in our case the district.

Relationship between Beliefs and Self-Reported Classroom Practice

The results support an understanding that teachers who hold beliefs that are more traditional show consistency between their beliefs and practice whereas teachers who hold more reformed beliefs demonstrate inconsistency. The two extreme cases, traditional-traditional and reformed-reformed, best illustrate these differences. The teachers who held traditional beliefs described practices that were consistent with a more traditional classroom practice. Specifically, they discussed that the relationship between teacher and student was that of dispenser and receiver, respectively. These teachers also discussed the use of the scientific method, demonstration labs, and foundational skill. The classroom practice described by the teachers in this case supports the findings of others who observed consistency between beliefs and practice for teachers who hold traditional beliefs (Bryan, 2012; Calderhead, 1996; Hashweh, 1996). In an investigation into what teachers' believe, Feyzioglu (2012) found that with more years of experience teachers held more traditional beliefs as measured with the TBI (Luft & Roehrig, 2007). Conversely, teachers who held reformed beliefs described their practice in a variety of different ways demonstrating inconsistency with their beliefs, and further supporting the idea that teachers who hold reformed beliefs have varying implementation of those beliefs (Hutner & Markman, 2017; Roehrig & Kruse, 2005; Trumbull et al., 2006; Wallace & Kang, 2005). Reformed-reformed teachers discussed their teaching approach to content as either to simplify the content, teach, and move on or to approach the content through application to achieve depth.

Additionally, teachers in the reformed-reformed case had conflicting understandings of what a lab was within the classroom. All but one described labs in a more traditional sense compared to the one teacher who described student developed and driven laboratories. Furthering the inconsistency between beliefs and practice is seen between the two cases: reformed-reformed and reformed-reformed with master's. The differences existing between these two (*teachers as manager* vs *teachers as facilitator* and *I direct content* vs *student choice*) further demonstrates the variety of different approaches to practices of teachers who held similar beliefs. Utilizing the TPB (Ajzen, 1991), the variety of difference self-reported classroom practice can be attributed to differences in teachers' behavioral beliefs regarding a more reformed classroom practice. Additionally, when teachers demonstrate that they have reformed beliefs, but these do not match their classroom practice, there exists a breakdown between their intentions and actual behavior (Ajzen, 1985). This conclusion supports findings discussed by other researchers (e.g. Fives & Buehl, 2012; Bryan, 2012) and our theoretical framework relating behavioral beliefs, attitudes, intentions, and behavior (Ajzen, 1985).

Transitional Zone

The results support the proposed idea for the creation of a transitional zone (Weinbrecht, 2018) for teachers belief where teachers can hold competing or conflicting beliefs and/or where beliefs do not always match their described practice. A transitional zone could help describe teachers whose beliefs are contradictory but not extreme. A transitional zone exists in the TBI and the results obtained from each case in this study support the idea that teachers can hold complex and contradictory beliefs that influences their practice. Investigating teacher development and transition, Boesdorfer (2017) found that integrating engineering into the classroom caused teachers to change their beliefs and practice to a more learner-entered focus. The groups that were defined by the Grid and Group theory application using the BARSTL (Weinbrecht, 2018) run on a continuum from traditional to reformed, similar to the results seen in the TBI. Even though the groups were defined by definite and limiting descriptors, it is important to know that the teachers do not hold beliefs that fit within one category. Rather the beliefs teachers held are varied and specific to their own context, background, and judgement. The TPB (Ajzen, 1985) supports our understanding that each teacher has a varied belief system that influences their actions and judgments. Teachers cannot hold behavioral beliefs in isolation; rather, they hold these beliefs in relation to normative and control beliefs. Additionally, teachers can hold competing beliefs and practice and could be in the process of navigating how these beliefs and practices are accepted within the larger culture, influence the instructional outcomes, or the perceived control they have on making these changes in the classroom. All of these factors are influenced by the context, background, and culture that each teacher works within specifically.

Further research is needed to better relate teachers' beliefs and actual classroom practices. Due to the limitations of this study, these results only explored how teachers described and showed their practice through an interview and lesson planning documents. Further research that allows for direct observation of classroom practice would enhance our understanding of the relationship between teachers' beliefs and practice. Additionally, we observed commonly held beliefs across grades, subjects, and buildings. Further research is needed to see if this phenomenon is observed in other districts and if differences exists between districts that result in a difference in teaching practice.

The implications of this study relate to our understanding of teacher development through higher education and professional development and implementation of institutional change. This study highlights the differences in teachers' beliefs and classroom practice that exist within one school district. Teachers with similar beliefs resulted in different classroom practices, which have implications for a district as a whole. Using the TBI, Luft and Zhang (2014) found that teachers' beliefs changed based on the school culture they taught within more than an induction program, thus the comparison between different districts might illustrate how the relationship between beliefs and classroom practice is influenced by school culture. Follow up with teachers, by colleagues or professional development providers, inside their classroom regarding their own development might provide an area for additional growth or change as teachers navigate their own practice. The implications for teachers relates to the idea that change proceeds through a process of transition and during this process parts of our belief systems and practice will be at odds with each other. Research supports that a critical part of change is the experience of disequilibrium (Hong, Greene, & Lowery, 2017) and is a dynamic, important development for science teacher identity (Beauchamp & Thomas, 2009; Carrier, Whitehead, Walkowiak, Luginbuhl, & Thomson, 2017). With further research into how additional professional development can change these beliefs and practice, might provide insights into ways the relationship between beliefs and practices is negotiated.

CHAPTER V

CONCLUSION

This research sought to identify secondary science teachers' beliefs about the teaching and learning of science and explore their self-reported classroom practices associated with their held beliefs. Utilizing a modern understanding of reformed science education beliefs (Sampson et al., 2013) and self-reported classroom practices through a cultural and context-based lens (Douglas, 1970, 1973, 1982), the research consisted of two studies, one quantitative and one qualitative.

The following research questions guided study 1:

- What are in-service secondary science teachers' beliefs about the teaching and learning of science?
    - Is there a significant difference in the Beliefs about Reformed Science Teaching and Learning (BARSTL) scores and teachers' demographics (i.e., gender, race, highest education level, and current grade taught)?

    - Does years of teaching experience predict BARSTL scores?
- What is the resulting Grid and Group cultural map when using teachers' beliefs as measured by the BARSTL?
    - Does the Grid and Group cultural map show demographics differences between teacher beliefs as measured by the BARSTL?
    - How do the dimension of Grid and Group explain teachers' beliefs about reformed science teaching and learning as measured by the BARSTL?

The following research questions guided study 2:

- What are secondary science teachers' beliefs and self-reported classroom practices?
- How do secondary science teachers' beliefs influence their self-reported classroom practices?

Summary of Each Study

The goal of study 1, titled *Secondary Science Teachers Beliefs about Science Teaching and Learning: An Application of Grid and Group Theory*, was to determine what secondary science teachers' beliefs were and how the application of Grid and Group theory could help categorize teachers based on their beliefs. Three major findings were presented. First, the overall population of teachers within the district held a more reformed perspective of the teaching and learning of science. While the majority of teachers held a more reformed perspective, some held conflicting beliefs. Second, it was observed that teachers who held a Master's degree had higher scores overall and on all four subscales when compared to those who did not hold a Master's degree indicating that they held a more reformed perspective. Third, creating a cultural map by applying the Grid and Group typology (Douglas, 1970, 1973, 1982) to teachers' scores on the Beliefs about Reformed Science Teaching and Learning (BARSTL) showed one major cluster of teachers in the reformed-reformed quadrant, but still differentiated teachers into each of the four quadrants (i.e., traditional-traditional, traditional-reformed, reformed-traditional, and reformed-reformed). Close examination of individual items on the BARSTL revealed that teachers held conflicting views within both traditional and reformed perspectives, supporting the creating of a transitional zone on the cultural map. The placement of teachers on the resulting cultural map (and significant difference between teachers who held a Master's degree and those who did not) informed the selection of participants for study two.

The goal of study 2, titled *Secondary Science Teachers Current Instructional Practices: A Case Study Approach,* was to explore secondary science teachers' self-reported classroom practices through multiple case studies bounded by teachers' beliefs about the teaching and learning of science. The results of this study focused on three areas: (a) cross-case belief regarding a focus on essential content, (b) consistency between traditional beliefs and practice but inconsistencies for reformed beliefs and practice, and (c) the support for a transitional zone. First, teachers within each case expressed that their practice supported the development of essentials that each student should master within their class. These essentials drove the focus of instruction for more traditional teachers and provided a launching pad into further investigations for teachers with more reformed practices. Second, the comparison between two extreme cases showed that teachers who held beliefs that are more traditional show consistency between their beliefs and practice whereas teachers who hold more reformed beliefs demonstrate inconsistency. Lastly, the results support the creation of a transitional zone on the cultural map for teachers' belief where teachers can hold competing or conflicting beliefs and/or where beliefs do not always match their described practice. The transitional zone represents teacher beliefs that do not exist in extremes, rather are balanced while still in contradiction. This transitional zone, similar to the ideas presented in the inconsistency perspective, acknowledges the complexity of the beliefs and practice relationship. The transitional zone also provides a method for more fluid understanding of the cultural map discussed in study one that shows the intersection between different understandings of the teaching and learning of science on a continuum rather than a ridged definition.

Overall Conclusions

The overall purpose of this study was to explore secondary science teachers' beliefs, self-reported classroom practice, and the relationship between these two variables. The results of the BARSTL showed that on average teachers within the sample had a more reformed perspective towards the teaching and learning of science. Within the sample, statistically significant differences were observed between teachers who held and did not hold a master's degree and the number of undergraduate science courses taken. While these demographic differences and the scope of this study do not provide enough evidence to correlate these differences with more reformed beliefs, it does suggest that teachers in this study who had these characteristics had more reformed beliefs. Additionally, response to the BARSTL statements indicated that teachers had a more reformed perspective with regard to students' actions and classroom behaviors while holding a more traditional perspective with regard to instructional practices.

Applying the *a priori* Grid and Group theory typology allowed for the visualization of the BARSTL scores along two dimensions, social incorporation and level of independence. By doing this, teachers were purposefully selected from the four different cultural map quadrants and an additional fifth group which consisted of those teachers holding a master's degree to conduct case studies on their self-reported classroom practice. While the *a priori* Grid and Group topology contains two areas, reformed-traditional and traditional-reformed, of contradictory beliefs, and these areas may seem unlikely, this research showed that teachers' beliefs and self-reported classroom practice support these contradictions. Noah demonstrated that he believed in a classroom driven by student questions and interests but he provided the source of knowledge for the students; that is student-directed while being teacher as dispenser. The results from both studies support the creation of a transitional zone on the Grid and Group typology that would categorize teachers' beliefs are balanced but in contradiction with each other but not extreme in their differences. The transitional zone might help to understand teachers who are in the process of integrating new beliefs or classroom practices, or where teachers' beliefs are in conflict but do not represent extreme differences. Additionally, the transitional zone might help to explain the well-integrated beliefs that are in conflict and how this translated into the self-reported classroom practices. Additional research must be conducted to further investigate if this differentiation is necessary or helpful. However, this transitional zone supports research done by others (e.g. Luft & Roehrig, 2007).

This study supports the understanding that beliefs and classroom practice are inconsistent with each other and that each are complex, messy, and unresolved (Bryan, 2012; Fives & Buehl, 2012). While each case study showed differences in self-reported classroom practice, each showed that teachers within the district have a focus on teaching the essentials of science. The differences between each case highlight areas of contradiction between the most recent reform agenda and the need for continued professional development.

Implications and Future Research

The implications of this study relate to understandings of the relationship between beliefs and practice, teacher development, and institutional change. As Yerrick et al. (1997) stated, teachers tend to rely on personal beliefs to guide their thinking and practice rather than following recommendations made by professional organizations and standards. This research allowed for an institutional overview of secondary science teachers' beliefs that allowed for grouping and visualization of their currently held beliefs. The cultural map created from the BARSTL results could allow for institutions and researchers to track change over time through professional development or implementation of curriculum. The application of Grid and Group theory allows for a view of teachers' beliefs from the perspective of a culture and could be used to address aspects of the culture impeding the change or implementation desired. While the application of Grid and Group Theory worked for this sample, further comparison between different populations and teacher characteristics could reveal aspects of teacher education and district culture that foster a more reform-based perspective. Nevertheless, "considerable adaptations of teachers' beliefs in order to align their practice with the philosophy of the reform" (Sampson et al., 2013, p. 12) still must occur in order to implement the goals of the current reform movement. This research illuminates the cultural aspect of this implementation and proposes a method to visualize these beliefs on a continuum.

Additionally, the results of this study support the inconsistency perspective that supports the understanding that beliefs do not necessarily match classroom practice. The assumption that a direct relationship between the two constructs exist is an oversimplification of the relationship and must be further explored. This study highlights the differences in teachers' beliefs and classroom practice that exist within one school district. In some cases, teachers with similar beliefs self-reported different classroom practices. The implications of varying beliefs and practices across the district indicates the need for additional teacher collaboration and professional development situated within their context, the classroom, addressing their specific needs as teachers navigate their own change in classroom practice. As teachers continue to grow, this study supports the idea that their espoused beliefs might not be the best indication of consistent, reform-based classroom practice. Due to the limitations of this study, these results only explored how teachers described and showed their practice through an interview and lesson planning documents. Further research that allows for direct observation of classroom practice would enhance our understanding of the relationship between teachers' beliefs and practice.

Implications for teacher development centers around the idea that change proceeds through a process of transition, and during this process, parts of our belief systems and practice will be at odds with each other. Further research into how additional professional development, experience, and changing district culture can affect these beliefs and practice, might provide insights into ways the relationship between beliefs and practices is negotiated. Additionally, a few commonly held beliefs regarding student actions and behaviors, a more traditional instructional approach, and a focus on mastering foundational knowledge were observed across grades, subjects, and buildings. Further research is needed to see if this phenomenon is observed in other districts and if there exists differences between districts that results in a difference in teaching practice.

This study found that secondary science teachers within the sample held more reformed beliefs regarding the teaching and learning of science. The application of Grid and Group

Theory (Douglas, 1970, 1973, 1982) allowed for the visualization of the held beliefs on a typology. The observed relationship between beliefs and self-reported classroom practice was consistent between traditional beliefs and classroom practice, but inconsistent between reformed beliefs and resulting classroom practice. This research supports the findings of other researchers regarding the complex, messy, and unresolved relationship between teachers beliefs and classroom practice (Bryan, 2012; Fives & Buehl, 2012). This study adds to the research by allowing for a new approach towards investigating the beliefs and practice relationship from a cultural and contextual approach. Additional research is needed to further explore the relationship between teachers' beliefs through a Grid and Group Theory application and direct observations of teachers' classroom practices, explore a transitional zone relating beliefs and classroom practice, and investigate the process of change caused by the beliefs and practice relationship.

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APPENDICES

Appendix A: Instructional Review Board Approval Letter

Oklahoma State University Institutional Review Board

Date: Friday, May 01, 2015

IRB Application No ED1553

Proposal Title: Relationship between reformed science teaching learning beliefs and classroom practices: A two-part study

Reviewed and Processed as: Expedited

Status Recommended by Reviewer(s): Approved **Protocol Expires: 4/30/2016**

Principal Investigator(s):

Luke Weinbrecht	Toni Ivey
1548 S. Delaware PL.	226 Willard
Tulsa, OK 74104	Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☒ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

The reviewer(s) had these comments:
This approval is for Teacher interviews and Teacher surveys at Union Public Schools only.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins in 219 Cordell North(phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Hugh Crethar, Chair Institutional Review Board

Appendix B: Beliefs About Reformed Science Teaching and Learning Questionnaire

Note: Used from Sampson et al. (2013) with permission by John Wiley and Sons.

How People Learn About Science

The statements below describe different viewpoints concerning the ways students learn about science. Based on your beliefs about how people learn, indicate if you agree or disagree with each of the statements below using the following scale:

SD: Strongly Disagree D: Disagree A: Agree SA: Strongly Agree

1. Students develop many ideas about how the world works before they ever study about science in school.	SD	D	A	SA
2. Students learn in a disorderly fashion; they create their own knowledge by modifying their existing ideas in an effort to make sense of new and past experiences.	SD	D	A	SA
3. People are either talented at science or they are not, therefore student achievement in science is a reflection of their natural abilities.	SD	D	A	SA
4. Students are more likely to understand a scientific concept if the teacher explains the concept in a way that is clear and easy to understand.	SD	D	A	SA
5. Frequently, students have difficulty learning scientific concepts in school because their ideas about how the world works are often resistant to change.	SD	D	A	SA
6. Learning science is an orderly process; students learn by gradually accumulating more information about a topic over time.	SD	D	A	SA
7. Students know very little about science before they learn it in school.	SD	D	A	SA
8. Students learn the most when they are able to test, discuss, and debate many possible answers during activities that involve social interaction.	SD	D	A	SA

Lesson Design and Implementation

The statements below describe different ways science lessons can be designed and taught in school. Based on your opinion of how science should be taught, indicate if you agree or disagree with each of the statements below using the following scale:

SD: Strongly Disagree D: Disagree A: Agree SA: Strongly Agree

9. During a lesson, students should explore and conduct their own experiments with hands-on materials before the teacher discusses any scientific concepts with them.	SD	D	A	SA
10. During a lesson, teachers should spend more time asking questions that trigger divergent ways of thinking than they do explaining the concept to students.	SD	D	A	SA
11. Whenever students conduct an experiment during a science lesson, the teacher should give step-by-step instructions for the students to follow in order to prevent confusion and to make sure students get the correct results.	SD	D	A	SA
12. Experiments should be included in lessons as a way to reinforce the scientific concepts students have already learned in class.	SD	D	A	SA
13. Lessons should be designed in a way that allows students to learn new concepts through inquiry instead of through a lecture, a reading, or a demonstration.	SD	D	A	SA
14. During a lesson, students need to be given opportunities to test, debate, and challenge ideas with their peers.	SD	D	A	SA
15. During a lesson, all of the students in the class should be encouraged to use the same approach for conducting an experiment or solving a problem.	SD	D	A	SA
16. Assessments in science classes should only be given after instruction is completed; that way, the teacher can determine if the students have learned the material covered in class.	SD	D	A	SA

Characteristics of Teachers and the Learning Environment

The statements below describe different characteristics of teachers and classroom learning environments. Based on your opinion of what a good science teacher is like and what a classroom should be like, indicate if you agree or disagree with each of the statements below using the following scale:

SD: Strongly Disagree D: Disagree A: Agree SA: Strongly Agree

17. Students should do most of the talking in science classrooms.	SD	D	A	SA
18. Students should work independently as much as possible so they do not learn to rely on other students to do their work for them.	SD	D	A	SA
19. In science classrooms, students should be encouraged to challenge ideas while maintaining a climate of respect for what others have to say.	SD	D	A	SA
20. Teachers should allow students to help determine the direction and the focus of a lesson.	SD	D	A	SA
21. Students should be willing to accept the scientific ideas and theories presented to them during science class without question.	SD	D	A	SA
22. An excellent science teacher is someone who is really good at explaining complicated concepts clearly and simply so that everyone understands.	SD	D	A	SA
23. The teacher should motivate students to finish their work as quickly as possible.	SD	D	A	SA
24. Science teachers should primarily act as a resource person, working to support and enhance student investigations rather than explaining how things work.	SD	D	A	SA

The Nature of the Science Curriculum

The following statements describe different things that students can learn about in science while in school. Based on your opinion of what students should learn about during their science classes, indicate if you agree or disagree with each of the statements below using the following scale:

SD: Strongly Disagree D: Disagree A: Agree SA: Strongly Agree

25. A good science curriculum should focus on only a few scientific concepts a year, but in great detail.	SD	D	A	SA
26. The science curriculum should focus on the basic facts and skills of science that students will need to know later.	SD	D	A	SA
27. Students should know that scientific knowledge is discovered using the scientific method.	SD	D	A	SA
28. The science curriculum should encourage students to learn and value alternative modes of investigation or problem solving.	SD	D	A	SA
29. In order to prepare students for future classes, college, or a career in science, the science curriculum should cover as many different topics as possible over the course of a school year.	SD	D	A	SA
30. The science curriculum should help students develop the reasoning skills and habits of mind necessary to do science.	SD	D	A	SA
31. Students should learn that all science is based on a single scientific method—a step-by-step procedure that begins with “define the problem” and ends with “reporting the results.”	SD	D	A	SA
32. A good science curriculum should focus on the history and nature of science and how science affects people and societies.	SD	D	A	SA

Appendix C: Demographic Survey

Secondary Science Teachers – Demographics

Please print your responses below.

Your Name (Last, First MI):		
Street Address		
City, State Zip-Code:		
Phone number:		
School E-mail:		
Gender:	☐ Male	☐ Female
What is your ethnicity?	☐ Hispanic or Latino ☐ Not Hispanic or Latino	
What is your race?	☐ American Indian/Alaskan ☐ Asian ☐ Native Hawaiian or Other Pacific Islander ☐ Black ☐ Hispanic ☐ White ☐ Other (please specify)______________________________	
Would you be interested in a follow up study about your current classroom practices?	☐ Yes ☐ No	

Educational Background

Please print your responses below. (Use back of this page if more space is required.)

Bachelor's Degree(s)	***Completion Date (MM/YY):___________***
Institution	
Major:	
Minor:	
	Please print your responses below. (Use back of this page if more space is required.)
Master's Degree(s)	***Completion Date (MM/YY):___________***
Institution	
Major:	
Minor:	
	Please print your responses below. (Use back of this page if more space is required.)
Other: ___________________________	***Completion Date (MM/YY):___________***
Institution	
Major:	
Minor:	
	Please print your responses below. (Use back of this page if more space is required.)

Teacher Preparation Program

Name of teacher preparation institution:					
In your teacher preparation program, how many courses have you taken that focused on general teaching or teaching strategy (i.e., non-content specific methods)?	☐ 0 courses	☐ 1-2 courses	☐ 3-4 courses	☐ 5-9 courses	☐ 10 or more courses
In your teacher preparation program, how many courses have you taken that focused on science specific teaching or teaching strategy (i.e., content specific methods)?	☐ 0 courses	☐ 1-2 courses	☐ 3-4 courses	☐ 5-9 courses	☐ 10 or more courses
How many ***undergraduate-level*** science courses have you taken?	☐ 0 courses	☐ 1-2 courses	☐ 3-4 courses	☐ 5-9 courses	☐ 10 or more courses
How many of these ***undergraduate-level*** science courses were in the area that you currently teach?	☐ 0 courses	☐ 1-2 courses	☐ 3-4 courses	☐ 5-9 courses	☐ 10 or more courses
How many ***graduate-level*** science courses have you taken?	☐ 0 courses	☐ 1-2 courses	☐ 3-4 courses	☐ 5-9 courses	☐ 10 or more courses
How many of these ***graduate-level*** science courses were in the area that you currently teach?	☐ 0 courses	☐ 1-2 courses	☐ 3-4 courses	☐ 5-9 courses	☐ 10 or more courses

Did you enter teaching through an alternative certification program? (*An alternative program is a program that is designed to expedite the transition of non-teachers to a teaching career, for example, a state, district, or university alternative certification program.)*	☐ Yes ☐ No
How long did your student teaching last?	☐ I did not participate in a student teaching program ☐ 4 weeks or less ☐ 5-7 weeks ☐ 8-11 weeks ☐ 12 weeks or more

Current Teaching Experience

Please print your responses below.

<table>
<tr><td>Name of your Current School</td><td colspan="7"></td></tr>
<tr><td>In what year did you begin teaching in THIS school?</td><td colspan="2"></td><td colspan="2">How many years have you taught at THIS school?</td><td colspan="3"></td></tr>
<tr><td>In which grades are your STUDENTS that you currently teach at THIS school? (Please mark all that apply.)</td><td>☐ 6
# of years ______</td><td>☐ 7
# of years ______</td><td>☐ 8
# of years ______</td><td>☐ 9
# of years ______</td><td>☐ 10
# of years ______</td><td>☐ 11
# of years ______</td><td>☐ 12
# of years ______</td></tr>
<tr><td>Please place a check by all science courses for which you are currently responsible for teaching. If you are not teaching a science course, please indicate that you are currently not teaching a science course.</td><td colspan="7">☐ Not currently teaching a science course
☐ Earth sciences
☐ Science, general
☐ Integrated Science
☐ Biology or life sciences
☐ Physical Sciences
☐ Chemistry
☐ Physics
☐ Other (please specify):________________________________</td></tr>
<tr><td>In what year did you begin teaching, either full-time or part-time?</td><td colspan="7"></td></tr>
<tr><td>How many total years have you taught?</td><td colspan="7"></td></tr>
</table>

Previous Teaching Experience

Please print your responses below.

<table>
<tr><td>Past School Name and District</td><td colspan="7"></td></tr>
<tr><td>In what year did you begin teaching in THIS school?</td><td colspan="2"></td><td colspan="3">How many years did you teach at THIS school?</td><td colspan="2"></td></tr>
<tr><td rowspan="2">In which grades did you teach? (Please mark all that apply.)</td><td>☐ pK
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# of years
______</td></tr>
<tr><td>Please place a check by all science courses for which you are were responsible for teaching. If you are not teaching a science course, please indicate that you are currently not teaching a science course.</td><td colspan="7">☐ Did not teach a science course   ☐ Earth sciences
☐ Science, general   ☐ Integrated Science
☐ Biology or life sciences   ☐ Physical Sciences
☐ Chemistry   ☐ Physics
☐ Other (please specify):______________________________</td></tr>
</table>

<table>
<tr><td>Past School Name and District</td><td colspan="7"></td></tr>
<tr><td>In what year did you begin teaching in THIS school?</td><td colspan="2"></td><td colspan="2">How many years did you teach at THIS school?</td><td colspan="3"></td></tr>
<tr><td rowspan="2">In which grades did you teach? (Please mark all that apply.)</td><td>☐ pK
# of years
______</td><td>☐ K
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# of years
______</td></tr>
<tr><td>Please place a check by all science courses for which you are were responsible for teaching. If you are not teaching a science course, please indicate that you are currently not teaching a science course.</td><td colspan="7">☐ Did not teach a science course ☐ Earth sciences
☐ Science, general ☐ Integrated Science
☐ Biology or life sciences ☐ Physical Sciences
☐ Chemistry ☐ Physics
☐ Other (please specify):______________________________</td></tr>
</table>

**** If you have additional teaching positions, please list them on the reverse side.**

Teaching Certifications

	Please print your responses below. (Use back of this page if more space is required.)
Please list all current teaching certifications.	
Do you hold a National Board Certification?	☐ Yes ☐ No, but I am currently seeking NBPT certification ☐ No, but I am not currently seeking NBPT certification
If so, please list the content areas you currently hold under your National Board Certification.	

Appendix D: Semi-Structured Interview Protocol

Introduction Statement

1. I want to first start out by allowing you to talk and share about your current and past experiences as a science teacher. This can include, but is not limited to, student successes stories, well-developed lessons, and experiences of growth as a teacher. This is an open-ended questions, so feel free to share what you would like so I get to know you as a teacher.

Teacher Beliefs Interview Protocol (Luft and Roehrig, 2007)

1. How do you maximize student learning in your classroom?
2. How do you describe your role as a teacher?
3. How do you know when your students understand?
4. In the school setting, how do you decide what to teach and what not to teach?
5. How do you decide when to move on to a new topic in your classroom?
6. How do your students learn science best?
7. How do you know when learning is occurring in your classroom?

Science Teacher Professionalism Protocol (Weinbrecht & Ivey)

1. How do you learn science the best?
2. When you are teaching a new or unfamiliar science topic, how do you prepare to teach that topic?
3. How do you go about creating science lessons for your class?

4. In the past three years, how many hours/days of professional development related to science teaching or science content have you had?
    a. Was the focused just on science content? Or just science pedagogy? Both?
    b. Who provides this PD? District? University? State?
        i. Do you seek it out on your own?
5. When you are looking for science professional development, what do you look for?
6. What kinds of science education leadership roles do you hold in the school? district? Community? State? Nation?

Instructional Documents Follow-up Questions

1. Questions will be developed before interview based on submitted lesson plan. The follow represents sample questions that could be used:
    a. Why did you plan this for your particular grade level or class?
    b. What are the objectives for this lesson?
        i. Why did you select these objectives?
        ii. How does your lesson address these objectives?
        iii. How do you plan to measure student understandings of these objectives?
    c. What prior knowledge do you expect students to bring into the lesson?
    d. What, if any, challenges to your foresee in your lesson? Why?
    e. If you have completed this lesson with student before,
        i. Is there anything that you are really proud of regarding how the lesson went?
        ii. Is there anything that you would change about your lesson?

iii. Do you feel that you taught the objective effectively? Why or why not? How do you know?

iv. Do you feel that your students mastered the objective? How do you know? Maybe

v. How do the results of this lesson direct your preparation of your next lesson? Why or why not?

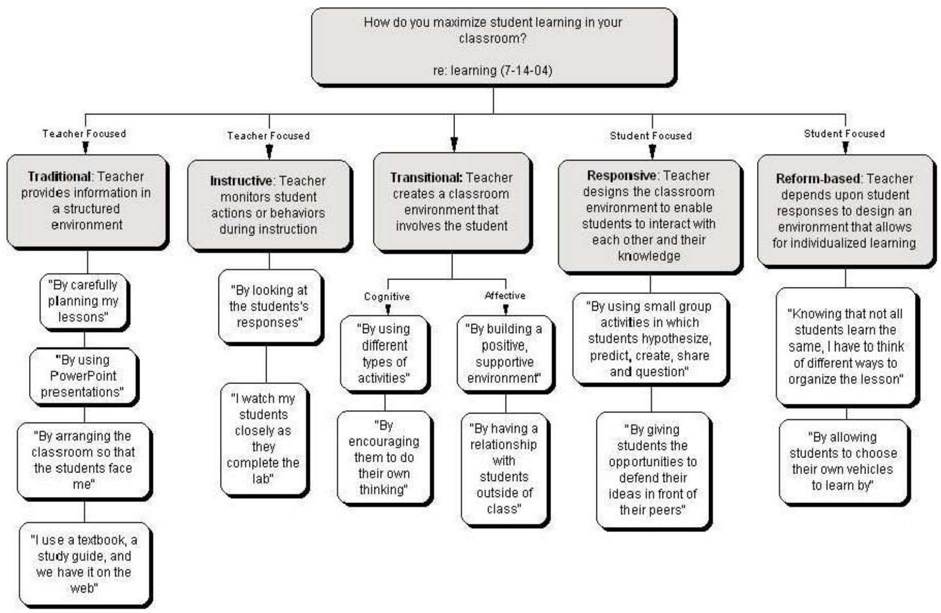
f. Are there any challenges that you are currently facing in your teaching?

2. Is there anything additional that you would like to add that was not covered in this interview?

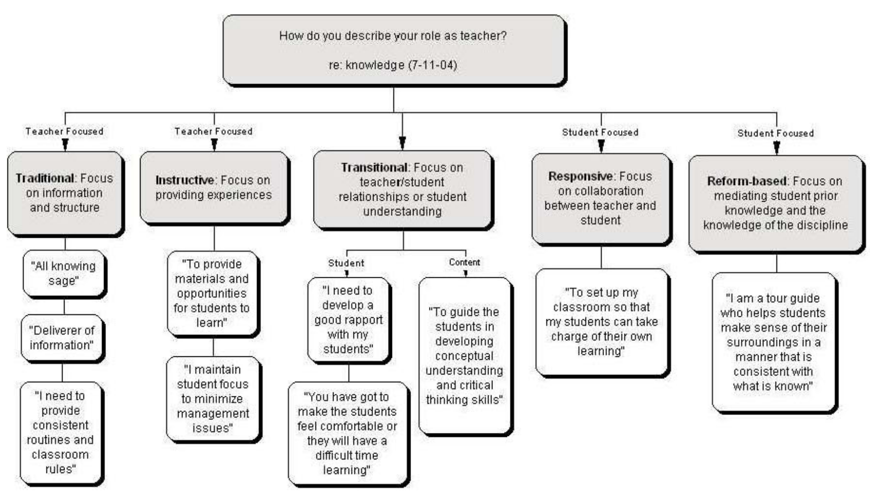
Appendix E: Teacher Belief Interview Question Descriptors.

Used from Luft and Roehrig (2007) with permission by Electronic Journal of Science Education.

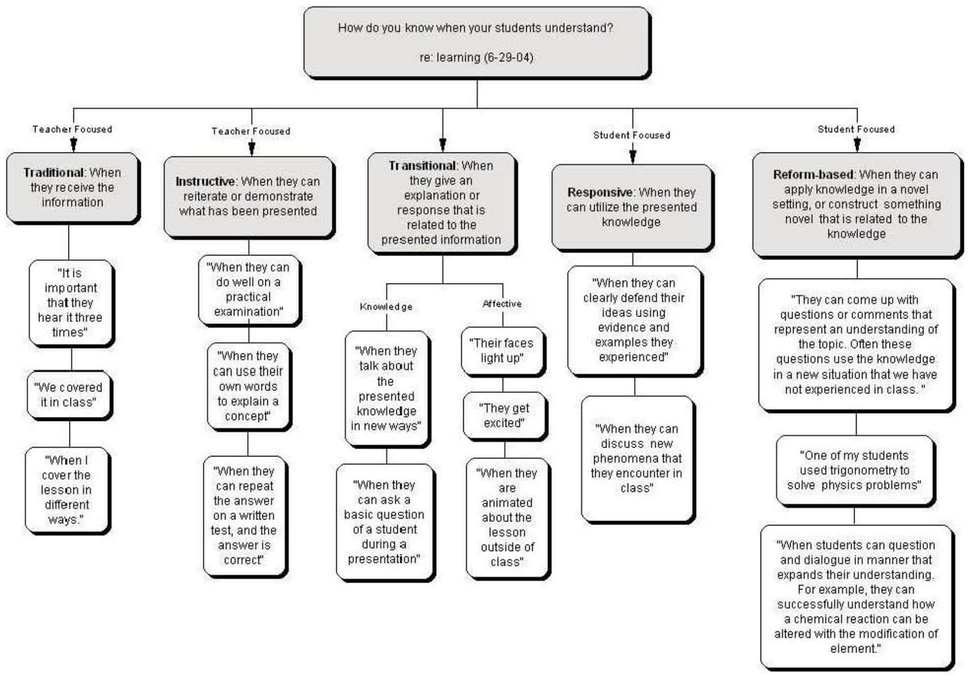
Question 1



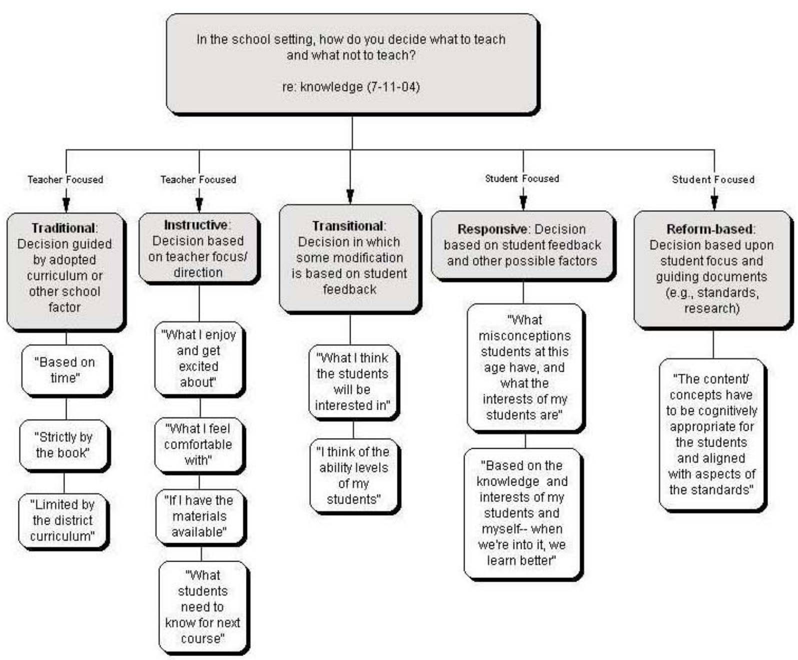
Question 2



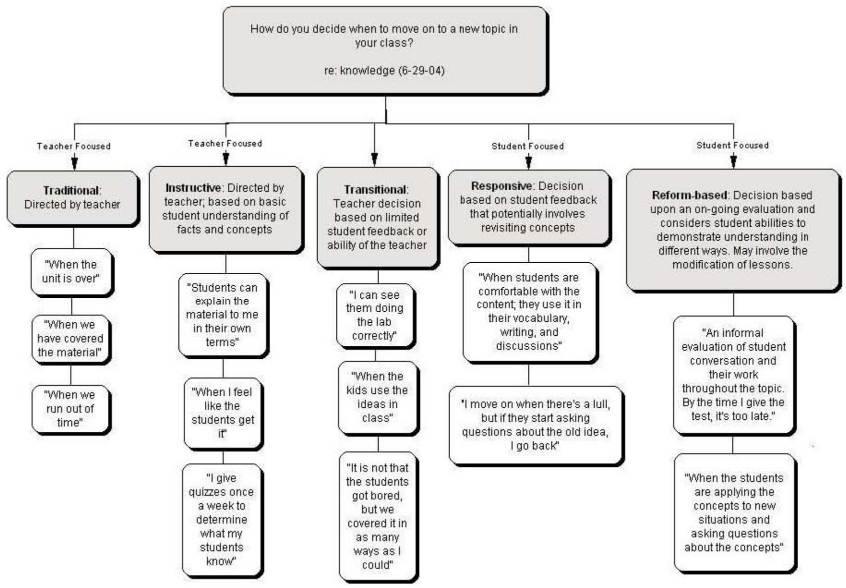
Question 3



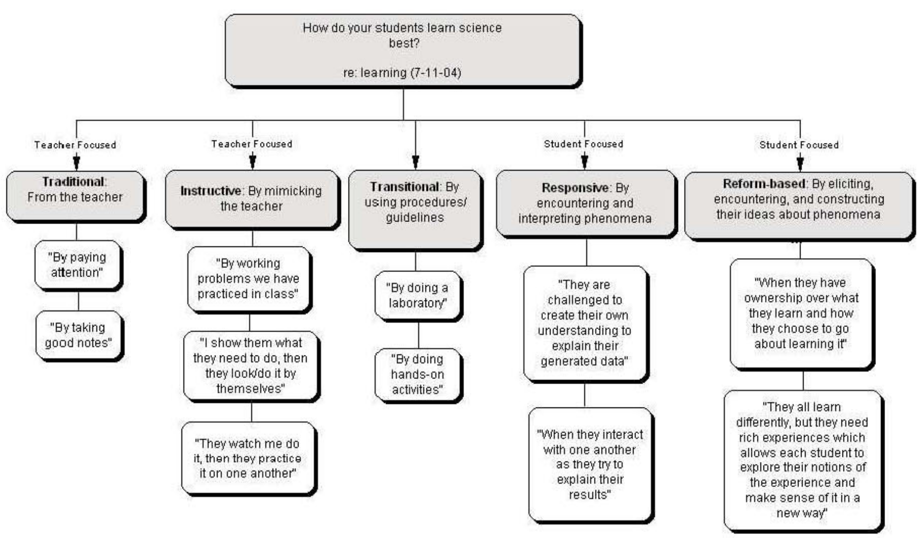
Question 4



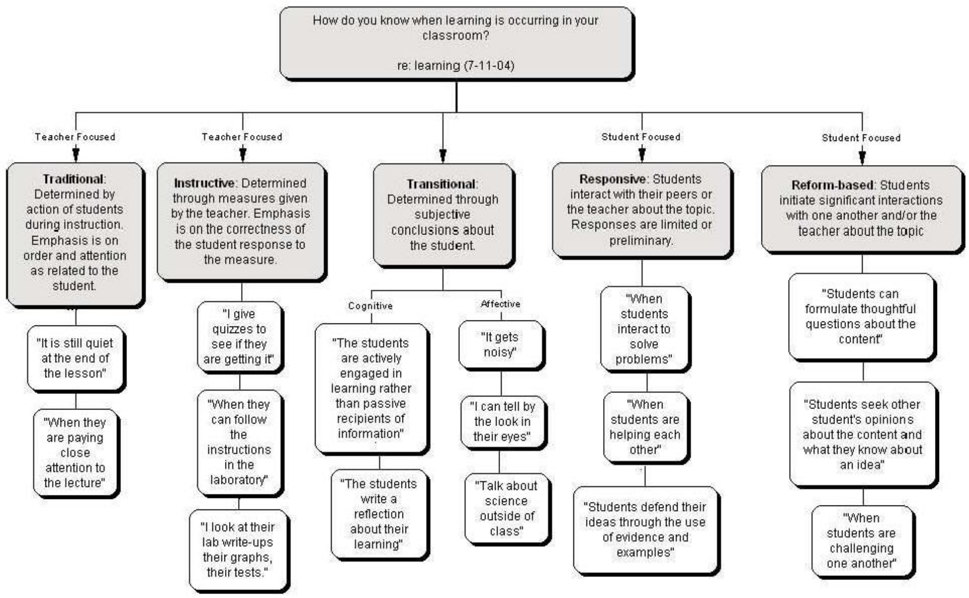
Question 5



Question 6



Question 7


How do you know when learning is occurring in your classroom?
re: learning (7-11-04)
Teacher Focused
Teacher Focused
Student Focused
Student Focused
Traditional: Determined by action of students during instruction. Emphasis is on order and attention as related to the student.
Instructive: Determined through measures given by the teacher. Emphasis is on the correctness of the student response to the measure.
Transitional: Determined through subjective conclusions about the student.
Responsive: Students interact with their peers or the teacher about the topic. Responses are limited or preliminary.
Reform-based: Students initiate significant interactions with one another and/or the teacher about the topic
"It is still quiet at the end of the lesson"
"When they are paying close attention to the lecture"
"I give quizzes to see if they are getting it"
"When they can follow the instructions in the laboratory"
"I look at their lab write-ups their graphs, their tests."
Cognitive
Affective
"The students are actively engaged in learning rather than passive recipients of information"
"The students write a reflection about their learning"
"It gets noisy"
"I can tell by the look in their eyes"
"Talk about science outside of class"
"When students interact to solve problems"
"When students are helping each other"
"Students defend their ideas through the use of evidence and examples"
"Students can formulate thoughtful questions about the content"
"Students seek other student's opinions about the content and what they know about an idea"
"When students are challenging one another"

Appendix F: Sample Lesson Plan with Interview Questions

Lesson Plan for Thursday, December 10th, 2015

Class: Environmental Science

Learning Objective:

- Students will be able to explain how organisms affect and are affected by the environment and other organisms.
  - Explain the conditions necessary for a species to become invasive

Materials used: Laptop computers, attached worksheet, poster board, markers, and colored pencils

Background:

Over the last several weeks, we have been studying Population Ecology, Evolution, and Community Ecology. This unit covers:

- How the environment affects the density and distribution of a population and how fast that population may grow under certain environmental conditions.
- Change over time is discussed as it relates biological evolution, genetic drift, and allopatric speciation
- Predator-prey relationships, and symbiotic relationships.
- The unit ends with a study on primary succession after disasters and how invasive species threaten environments.

Plan:

Students are all assigned a laptop computer and a specific animal to research. Each animal assigned is designated an invasive species by 1 or more environmental groups. Students are expected to research their assigned animal, answer the accompanying questions and make notes of additional interesting information. Students will have one day to perform research in class, though they may continue to do research at home. Students will have an additional day to put together a poster board explaining their creature to the rest of the class. After two days of research and work, students will present their infographic to the class to be displayed in the classroom. Each student will then write down one interesting fact that is found on each presentation.

Assessment:

Students will be assessed according to time management skills, presentation of factual information, creativity, and the relevant notes taken from other students' work.

10% of the grade will be determined by the student's ability to remain on task and finish in a timely manner. 60% of the grade will be determined by the student's ability to provide 10 relevant facts about their animal from a reliable and documented source. 20% of the grade will be determined by the creativity of their poster board. Effort, not artistic skill, is required. The final 10% of this project will be given for attention to and notes pertaining to other students' presentations.

Desired Outcome:

Students will be able to recognize and explain what conditions allow a species to become invasive and will be able to evaluate the effects of an invasive species upon the local environment.

Instructional Documents Follow-up Questions

1. Questions will be developed before interview based on submitted lesson plan. The follow represents sample questions that could be used:
   a. Why did you plan this for your particular grade level or class?
   b. What are the objectives for this lesson? ** **Objectives listed on lesson plan**
      i. Why did you select these objectives?
      ii. How does your lesson address these objectives? ** **unprompted answer during interview**
      iii. How do you plan to measure student understandings of these objectives?
   c. What prior knowledge do you expect students to bring into the lesson?
   d. What, if any, challenges to your foresee in your lesson? Why?
      i. Added ** You said this lesson reached the "rough students", how so?
   e. If you have completed this lesson with student before,
      i. Is there anything that you are really proud of regarding how the lesson went? ** **unprompted answer during interview**
      ii. Is there anything that you would change about your lesson? ** **unprompted answer during interview**
      iii. Do you feel that you taught the objective effectively? Why or why not? How do you know?
      iv. Do you feel that your students mastered the objective? How do you know? ** **unprompted answer during interview**
      v. How do the results of this lesson direct your preparation of your next lesson? Why or why not?
   f. Are there any challenges that you are currently facing in your teaching?
2. Is there anything additional that you would like to add that was not covered in this interview?

VITA

Luke Wm. Weinbrecht

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Thesis: RELATIONSHIP BETWEEN REFORMED TEACHING AND LEARNING BELEIFS AND CLASSROOM PRACTICE: A TWO-PART STUDY

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Completed the requirements for the Doctor of Philosophy in Education at Oklahoma State University, Stillwater, Oklahoma in December, 2017.

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