FIRST-YEAR SECONDARY SCIENCE TEACHERS’ BELIEFS ABOUT LABS:
INVESTIGATING CONNECTIONS BETWEEN ESPoused BELIEFS AND CLASSROOM ACTIONS

by

RACHEL E. FOSTER
(Under the Direction of Lynn A. Bryan)

ABSTRACT

This study examines three first-year secondary science teachers’ espoused beliefs about laboratories and their classroom actions. From a cognitive constructivist perspective, I conducted case studies to examine the beliefs that Caroline, Jake, and Lane held about laboratory teaching and the tensions that emerged when their espoused beliefs and classroom actions were in conflict.

From an analysis of interview, observation, and archival data, I constructed a profile of each first-year teacher’s beliefs about science laboratories. Caroline, Jake, and Lane each held beliefs about the purpose and the structure of laboratories. Caroline’s most salient belief concerned the purpose of laboratories as motivators. Caroline encountered tensions in thinking about laboratory teaching as a result of inconsistencies between her desire for students to have fun and their apathy toward engaging in laboratories. Jake’s most salient belief involved his need
to control student behavior and laboratory procedures. Jake’s tensions in thinking about laboratory teaching emerged due to inconsistencies between his desire for student-centered learning and his need to maintain control of student behavior. Additionally, a tension emerged between Jake’s espoused student-centered beliefs and his perception of his students’ lack of confidence. Lane’s most salient belief focused on laboratories as useful tools for verifying lectured course material. Lane encountered tensions in thinking about laboratory teaching as a result of inconsistencies between her espoused student-centered beliefs and her desire to meet the expectations of her mentor teacher.

The findings contribute to an understanding of the inconsistencies between the espoused beliefs and classroom actions of first-year teachers. Their struggles to bring their beliefs about laboratories into concert with the realities of their classrooms and the unique challenges of beginning science teachers are highlighted. Furthermore, the findings underscore the significance of identifying and challenging preservice teachers’ beliefs early in teacher education programs in an effort to align them with reform efforts toward more student-centered teaching. Implications for science teacher education programs are discussed and suggestions are made for future research.

INDEX WORDS: Teacher Beliefs, Laboratories, Science Education, Beginning Teachers
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A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA
2004
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DEDICATION

Dedicated to my mother who taught me to love science and learning and who teaches me every day to love life. You are my rock, my inspiration, my friend. And to my father who I miss with all that I am, your absence breaks my heart. You taught me to take risks, be strong, and have the courage of my convictions. Words cannot adequately express my gratitude and overwhelming love.
ACKNOWLEDGEMENTS

I would like to gratefully acknowledge the tireless support of Dr. Lynn A. Bryan throughout my scholarly pursuits at the University of Georgia. During the course of my studies, her knowledge, insight, and wisdom guided my work and my development as a science educator. As a mentor and friend, she supported my interests and gave me the confidence to pursue my goal of putting myself in a position to contribute to the improvement of science education. I cannot thank Dr. Bryan enough. She is an exceptional role model as I begin my career. I am indebted to her and can only hope to achieve what she believes I can.

In addition, I am thankful to the other members of my committee, Dr. Kathleen deMarrais, Dr. Tom Koballa, Dr. Steve Oliver, and Dr. Carolyn Wallace for their interest in my work and in my future. Each of them gave of their time and energies to make this process a positive learning experience for me. They refined my thinking about beliefs and laboratories and challenged me to go beyond what I knew, to a deeper understanding.

My family and friends also deserve special recognition because, while they were not asked to read and discuss my research, they bore the emotional side of this process. None of this would have been possible without these incredible people that listened, laughed, and loved despite my many moods. They shared my burdens and deserve to share my success. My family has always been supportive. They stood by me and kept me grounded throughout my life and my relentless pursuit of a career in science teaching. They were particularly encouraging during my doctoral program and I cannot thank them enough for their wisdom, love, and prayers. My friends, Connie, Tiffany, Karen, and Leslie, deserve endless thanks for their humor, kindness,
honesty, and support. I do not know what I would have done without their strength and belief in me.

I also wish to sincerely thank Caroline, Jake, and Lane for their participation in this research. They generously invited me into their classrooms during a time when they were learning to teach. It took tremendous courage to take that step. As personal as beliefs are, the fact that Caroline, Jake, and Lane openly engaged in this research is something for which I am very grateful. They welcomed me into their busy lives and helped me better understand the process of learning to teaching science laboratories. Beyond that, they are good people and are becoming good teachers. Working with them is an experience that will guide my future research and is an opportunity that I will always value.
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CHAPTER ONE
INTRODUCTION

Laboratory activities appeal as a way of allowing students to learn with understanding and at the same time, engage in a process of constructing knowledge by doing science. (Tobin, 1990, p. 405)

For over a century, the role of the laboratory has been a central and distinctive aspect of science classrooms (American Association for the Advancement of Science, 1990; Blosser, 1983; Hofstein & Lunetta, 2003; Lavonen, 2004; National Research Council, 1996; 2000; Séré, 2002; Tobin, 1990; Wellington, 1998). Laboratories, which Tobin (1990) called the “essence of science”, have the potential to provide rich opportunities to engage students in authentic, meaningful learning experiences. However, teaching and learning in the laboratory was considered by Tamir (1989) to be “a persistent and recurring problem in the practice of science education” (p. 60) and has come under increased scrutiny in the past two decades (Blosser, 1983; Hodson, 1990; 1998; Hofstein & Lunetta, 1982; Lazarowitz & Tamir, 1994; Millar, 1998; Roth, McRobbie, Lucas, & Boutonné, 1997; Séré, 2002; Tamir, 1989; Tobin, 1990; Wallace, Tsoi, Calkin, & Darley, 2003; Wellington, 1998; Woolnough, 1998). In fact, laboratories constitute what Hodson (1990) called a “powerful, myth-making rhetoric” in which, despite little empirical support of their value as currently used, are touted as the best possible ways for students to learn science (AAAS, 1990; NRC, 1996; 2000; U.S. Department of Education, 1986). National initiatives aimed at reforming science education (AAAS, 1990; NRC, 1996; 2000) maintain the
importance of laboratories to teaching and learning science despite being under scrutiny for the past two decades. Yet assumptions about their effectiveness were largely unexamined prior to the late 1990s (Roth, 1994; Roth et al., 1997).

Reform efforts (AAAS, 1990; NRC, 1996; 2000) encourage teachers to engage their students in laboratory learning as an integral part of their science teaching. Yet, to date, many teachers have not translated reform-based teaching into their classroom actions in ways that result in meaningful learning (Bryan, 2003; Gardiner & Farranagher, 1997; Haney & McArthur, 2002; Haney, Czerniak, & Lumpe, 1996; Luft, 2001; Lumpe, Haney, & Czerniak, 2000; Simmons et al., 1999; Thomas, Pedersen, & Finson, 2001; Yerrick, Parke, & Nugent, 1997). In the past, many teachers considered laboratory learning to be frivolous (Lortie, 1975) and a largely auxiliary, dispensable aspect of science classes (Tobin & Gallagher, 1987). In 2004, teachers appear to place greater value on laboratory use (e.g. Luft 2001), but the realities of their beliefs and the complexities of their classrooms result in significant barriers to the implementation of reform-based actions (Bryan, 1999; 2003; Luft & Patterson, 2002; Salish I Project, 1997).

Science education research on the value of laboratories, and the mismatch between the intentions of reforms efforts, teachers’ beliefs about laboratories, and classroom realities represent significant divides for science education. Understanding the beliefs of teachers learning to teach science and incorporate laboratories allows insight into an important aspect of laboratory implementation that is vital to understanding their effectiveness for science teaching, and has the potential to reveal where teaching in the laboratory becomes problematic. Examining this process for first-year teachers is especially telling as it is the time between teacher education and the label of “experienced” teacher. Before discussing the fundamental nature of first-year
teachers’ beliefs to the current study, I examine the historical context that resulted in the current understanding of laboratories in science education at the beginning of the twenty-first century. I start with the early history of labs and then turn to the dramatic changes in the sciences that occurred beginning in the 1960s to provide context for the importance of laboratories in science classrooms. The past hundred years have seen movements toward, away from, and back toward laboratory teaching. I then return to the importance of beliefs for understanding science classrooms and laboratories.

The Historical Background of Laboratories

The laboratory as a central aspect of science learning in schools gained prominence in mid-nineteenth century chemistry classes because, according to Layton (1990), it taught students how to learn. This philosophy of the usefulness of the laboratory for science teaching developed from studies of the classics and mathematics and was soon applied to physics and biology (Hodson, 1993a). During this time, the laboratory was used primarily to confirm theory taught in lecture and was secondary to teacher demonstrations as a way to explaining scientific phenomena (Hodson, 1993a). A shift occurred near the end of the nineteenth century, toward laboratories as training in the scientific method—doing science in order to understand science—replacing for a time, the emphasis on demonstrations. However, throughout the early twentieth century, teacher demonstrations reemerged as the primary means of explaining science, due to declarations by many science educators, that laboratory learning represented a wasteful practice in schools (Hodson, 1993a). It was not until the 1950s and 1960s that the tide turned again toward laboratories. In the United States, this return to laboratories was accompanied by a focus on their “capacity to develop reasoning skills, encourage observation and provide direct contact with the physical world” that demonstrations failed to offer (Hodson, 1993a, p. 86).
Discussions of the importance of science teaching and learning in the laboratory had taken place for a century by the time that scientific advances began to exponentially change the shape of the way science and science education were understood. The focus of learning science shifted rather dramatically in the 1960s to more student-centered learning in which students were encouraged to learn science by doing what scientists do (Tamir & Lunetta, 1981). Demonstrations, while time saving, less expensive, and generally easier to control, took a back seat to students conducting experiments themselves (Hodson, 1993a). This shift from demonstrations to student-centered investigations forms the context that informs this study regarding the centrality of the science laboratory to science teaching. While the reasons for doing practical work in science have changed slightly over the past forty years, the appeal of the laboratory for teaching science in science education research and in efforts to reform science education has remained remarkably strong.

In 1962, Joseph Schwab made an urgent appeal to science and science educators to address the growing schism between the way science was being done and the way schools were teaching science. Five years prior to the publication of *The Teaching of Science as Inquiry* (Schwab, 1962), the Russians launched the Sputnik satellite, which, among other advances, spurred rapid scientific discovery that continues today. As a result, science underwent growth and development in the United States, while science education was reported to have taken quite the opposite path (Schwab, 1962). What Schwab proposed to fill the ever-widening gap between science and science education was “…ironically, that science be taught as science…science as a product of fluid enquiry” (1962, p. 4).
Through the inclusion of activities that teach students important scientific concepts and skills, Schwab suggested ways to reverse the trend that was separating science and science education. His suggestions for science classrooms extend Dewey’s (1933) notions of how we think and included: that facts no longer be treated as self-existing givens; that scientific knowledge be seen as fragile and subject to change; that there is a continuing revision of scientific knowledge; that students are engaged in discovery of the limitations of present knowledge; that laboratories would lead rather than follow the classroom phase of teaching; that materials would exhibit science as inquiry; that teachers would develop new skills and habits; and that discussions would take place regarding the defensibility of arguments and answers (Schwab, 1962). According to both Schwab (1962) and Dewey (1933), students could be expected to learn best by engaging in authentic science activities as extensions of their own experiences.

In addition to Schwab’s work, major curriculum reforms of the 1960s placed laboratory work squarely in the center of science education (e.g. BSCS, PSSC, CHEM Study as cited in Hodson, 1993a). Since the 1960s, research on teaching and learning in the science classroom has significantly impacted our understanding of the position of the laboratory as a place to see and do science. Among the current intended purposes for laboratory work are enhancing student motivation, teaching laboratory skills, learning scientific knowledge, developing insight into the scientific method, and developing scientific attitudes (Hodson, 1993a). With these purposes in mind, I move to a driving force in science education today—the reforms of the late twentieth century.
Recent Science Education Reforms

Building on Schwab’s work and research on the centrality of the laboratory to science education, national efforts to reform science education in the United States focus on learning science in ways best suited for the laboratory. In 1990 (AAAS), 1996, and 2000 (NRC), national science education reform efforts suggested that scientific content learning would be improved through student-centered, inquiry-based instruction. In addition to these reform efforts, the National Science Teachers’ Association (NSTA), and the Georgia Science Teachers’ Association (GSTA) published position statements on the importance of laboratory work, and the importance of inquiry-based science teaching and learning to improve science education (NSTA, 1990; GSTA, n.d.). Because the current study took place in the state of Georgia, I included the following excerpt from the GSTA position statement on laboratory teaching and learning to provide perspective:

The Georgia Science Teachers Association supports science instruction that will enable all K-12 students to achieve scientific literacy and to prepare them for making future career choices. Instruction in science must involve students in hands-on investigations based on sound scientific concepts and real world situations of interest and relevance to the students. Appropriate settings, significant time, and sufficient materials must be provided for laboratory experiences that allow development of the skills necessary for the processes of scientific investigations as well as the communication and the conceptualization of scientific phenomena. Since laboratory experiences are of critical importance in the process of developing students’ cognitive and affective understanding of
science, the Georgia Science Teachers Association makes the following recommendations:

- All science classes, K-12, must include a minimum of 25% of instructional time in inquiry-based laboratory and investigative experiences.

- Laboratory experiences must be supported with science targeted funding at the system and building level. This funding should be sufficient for each K-12 student to have hands on experiences. Sufficient amounts of current, operable equipment and materials must be provided to support these hands on experiences.

- …Local and state assessment of student performance must reflect the full range of student experience in science, including hands on experience. Performance based assessments of inquiry learning and science process skills must be included in the assessment program (GSTA, n.d.).

Both NSTA (1990) and GSTA (n.d.), as well as AAAS (1990) and NRC (1996; 2000) expect teachers to frequently engage students in authentic scientific investigations. With national and state position statements and national reforms recommending a more student-centered approach to laboratory teaching and learning, science teachers in the twenty-first century are encouraged to break free of reliance on traditional, didactic methods.

The Science Laboratory

Laboratories are central to secondary science teaching (AAAS, 1990; Blosser, 1983; Hofstein & Lunetta, 2003; Lavonen, 2004; NRC, 1996, 2000; Tobin, 1990; Wellington, 1998). In fact, their importance is “a philosophy that often is enshrined in legislation and policy at state
and district level” (Tobin, 1990, p. 403); however, the potential of laboratories to enhance student learning has not yet been achieved (Blosser, 1983; Hodson, 1990; 1998; Hofstein & Lunetta, 1982; Lazarowitz & Tamir, 1994; Millar, 1998; Roth et al., 1997; Séré, 2002; Tobin, 1990; Wallace et al., 2003; Wellington, 1998; Woolnough, 1998). It is interesting then that science education theory and reform efforts (AAAS, 1990; Hofstein & Lunetta, 1982; Lavonen, 2004; NRC, 1996, 2000; Tobin, 1990) suggest that laboratories hold promise in terms of promoting problem solving, intellectual development, scientific knowledge construction, improved student attitudes, and meaningful learning.

Student-centered pedagogies, as recommended in the reforms, that encourage students to investigate questions of interest to them, while manipulating variables and working collaboratively with their peers, are most effectively employed under the auspices of the laboratory. Laboratories come in many different varieties and can take place in classrooms or in the field. They can be used to introduce scientific phenomena, as an incorporated piece of a science unit, and as a means of verifying lessons learned through other means. For the purposes of this study, I define verification laboratories as a more traditional and didactic means of investigating a phenomenon that was previously introduced in class, and as a means of reinforcing course content. In contrast, inquiry-oriented laboratories can refer to a continuum of types that include those that provide students with a question or problem, asking them to come up with a solution on one end and those that provide inquiry aspects for one or more steps throughout the laboratory on the other. This study does not aim to investigate a specific laboratory-type, but rather the beliefs that three beginning secondary teachers had about laboratories of any persuasion.
While not the focus of this study of first-year teachers’ beliefs about laboratories, these recommendations toward inquiring science classrooms clearly point towards inquiry’s current emphasis in science education. Therefore, I define inquiry-based science teaching here, not as foundational to this study, but as an acknowledgement of its importance in efforts to shift science teaching away from a transmission model of teaching and learning which typically results in a presentation-recitation teaching approach (Lavonen, 2004), toward a more constructivist model that emphasizes students’ active generation and construction of knowledge. Definitions of inquiry by AAAS (1990), NRC (1996; 2000), Schwab (1962), Wallace and Kang (in press), and Welch, Klopfer, Aikenhead, and Robinson (1981) inform my understanding of inquiry as a way of thinking that encourages the investigation of the natural world based on students’ interests and questions. The National Science Education Standard’s document on inquiry (2000) defines the following as features of classroom inquiry:

- Learners are engaged by scientifically oriented questions.
- Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
- Learners formulate explanations from evidence to address scientifically oriented questions.
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
- Learners communicate and justify their proposed explanations. (p. 25)

Each of these elements represents currently yet unrealized goals for most science classrooms. Based upon the features of classroom inquiry described by the National Science Education Standards (NRC, 2000), inquiry-based classrooms in which the learner engages in scientifically
oriented questions, laboratory variations can range from learner-posed questions to students engaging in questions provided by their teacher or another source. This movement from student-directed to more teacher-directed inquiry along a continuum is also seen in the feature of inquiring classrooms that describes giving priority to evidence in which, at one end, the learner determines and collects the evidence, while on the other, he/she is given data and told how to analyze it (NRC, 2000). Following this same pattern for the feature of the learner formulating explanations based on evidence, on the student-centered end, the learner formulates explanations based on the evidence they collected, whereas, on the teacher-centered end, he/she is provided with evidence. With regard to the connection of explanations to scientific knowledge, the learner can do so independently, using other resources at one end of the continuum or be given possible connections, at the other. When communicating and justifying explanations in the inquiring classroom, the learner may form reasonable and logical arguments at the student-centered end of the continuum, or be given steps and procedures for communication at the other end. Didactic laboratories used to verify expository lessons are described by the teacher-centered end of this continuum (NRC, 2000). All can be useful choices for teaching science using laboratories depending upon the teachers’ goals for and implementation strategies, as well as a clear understanding of the goals and purposes by the students. Each can provide unique opportunities for creative and engaging alternatives to lecture and worksheets, but each represents distinctive challenges for science teachers (Luft & Patterson, 2002; Salish I Project, 1997). Laboratories have the potential to allow students to investigate natural phenomena while learning science and intellectual skills. Many scientific phenomena are difficult, if not impossible, to understand via lecture and worksheet-based teaching methods and laboratories offer a way to supplement and enhance science teaching and learning. The importance of laboratories to the development of
scientific knowledge suggests that the study of their use in classrooms is vital to understanding
and improving science teaching and learning.

Significance of the Study

Kagan (1992) suggested that teachers’ beliefs lie at the very heart of teaching. Additionally, they deeply impact all aspects of teaching and learning (Pajares, 1992). However, the challenge remains that until the last decade, teachers’ beliefs were not widely studied and have yet to be recognized in national reform efforts (AAAS, 1990; Czerniak & Lumpe, 1996; Haney & McArthur, 2002; NRC, 1996, 2000; Plummer & Barrow, 1998). The first year of teaching is the first time that teachers have the opportunity to enact their beliefs separate from constant, direct supervision. “An ideal time to explore beliefs is during the initial stages of a teacher’s career” (Bryan, 2003, p. 4). It is therefore, perhaps the ripest opportunity to see how or if teachers translate theory into practice. Every time they plan for and implement a laboratory they are likely thinking about what they are doing and why. They may not know whether or not a laboratory “works” because they may not have tried it before. It is this time that I sought to capture and examine.

Laboratories have long been supported as effective and important ways to teach science (e.g. Lavonen, 2004; Wellington, 1998) even though there exists contradictory empirical evidence that suggests that as currently used, laboratories are largely ineffective (e.g. Séré, 2002). However, there also exists research that supports the idea that the science laboratory is far too important to the success of science learning to be ignored (AAAS, 1990; NRC, 1996; 2000; U.S. Department of Education, 1986). Given the importance placed on the use of laboratories in science classrooms and given the integral and influential nature of teachers’ beliefs and that beliefs often mediate
teachers’ decision making, an understanding of the beliefs of those implementing laboratories is clearly fundamental.

Teachers learn to teach by teaching. Following pre-service teacher education programs, beginning teachers find themselves growing as teachers primarily through experience (Hoy & Rees, 1977); most of them do so alone (Plummer & Barrow, 1998), under less-than-ideal circumstances, where they face common problems including classroom management, student motivation, student differences (Veenman, 1984), insufficient supplies, lack of spare time (Dollase, 1992), large classes at schools with high rates of teacher turnover, a large number of inexperienced staff, and apathetic parents (Plummer & Barrow, 1998). Beginning teachers need support to negotiate the disparity between their beliefs and these classroom realities (Salish I Project, 1997), yet most do not receive the support that they need (Luft & Patterson, 2002). Additionally, for teachers not trained in inquiry teaching and learning techniques or supported during their implementation, reform recommendations are seldom enacted and are rarely sustainable (Bybee, 2000). The realities of being a new teacher in a science classroom compound these problems and often challenge their deeply held, personal beliefs about teaching and learning (including the science laboratory) in ways that result in adherence to their most stable, oldest beliefs (Bryan, 2003; Haney & McArthur, 2002; Richardson, 1996; Tobin, 1990).

Beginning teachers are learning to teach. They do not have a fully developed repertoire of tools or the knowledge with which to effectively handle every aspect of the teaching and learning environment, and the science laboratory provides an especially challenging place for indoctrination (Luft & Patterson, 2002; Salish I Project, 1997). They face unique challenges when their beliefs about science teaching collide with established school, parent, and administrative norms; student resistance to student-centered teaching techniques; and national
science education reform efforts that encourage student-centered teaching (e.g. AAAS, 1990; NRC, 1996; 2000). Additionally, “the variety of tasks that science teachers encountered, the greater number of preparations, and fewer established curriculum guides” contributed to an adherence of beginning science teachers to enacting more traditional practices, often despite espoused beliefs to the contrary (Luft & Patterson, 2002, p. 269). Prior to 2002, beginning science teachers were lumped with all beginning teachers; however, the complexities of the science classroom necessitated a reevaluation and new focus on the nature of science teaching as distinctive (Luft & Patterson, 2002). This distinct nature sets beginning science teachers apart and necessitates a study of their beliefs.

Purpose of the Study

Recognizing the importance of laboratory teaching and learning to science education, this study focuses specifically on first-year secondary science teachers’ espoused beliefs and classroom actions regarding laboratories as defined by each participant. I define espoused beliefs as those that the participants made explicit during interviews and often, during classroom interactions with me. Evidence of participants’ espoused beliefs may or may not have been present in their classroom actions. Hence, the purpose of this study was to investigate beginning secondary science teacher’s espoused beliefs and classroom actions within the context of using laboratories to teach in the their classrooms. Specifically, my goal was to gain a better understanding of teachers’ beliefs as they related to the planning, implementation, and assessment of laboratories. This study contributes to the field of research that focuses on secondary science teachers’ beliefs about laboratories and has implications for preservice science teacher preparation and beginning teacher support programs, by informing teachers,
administrators, policy makers, and science educators about the importance of recognizing, exploring, and respecting teachers’ beliefs.

Given the importance of laboratories to science teaching and teachers’ espoused beliefs and classroom actions to understanding teaching, I investigated the following overarching question: What are first-year secondary science teachers’ espoused beliefs and classroom actions regarding the use of laboratories in science teaching? In concert with the project goals, I examined five additional questions that framed this study:

- What do first-year secondary science teachers believe a laboratory is?
- What do first-year secondary science teachers believe are the purposes of laboratories in science teaching?
- How do first-year secondary science teachers plan for, implement, and assess laboratories they use?
- What experiences do first-year secondary science teachers identify as influencing their beliefs about laboratories?
- How do first-year secondary science teachers believe students learn science and what do they believe their role is in this process?

I begin the following chapter with the theoretical framework that informed my work with first-year teachers’ beliefs about laboratories. The review of the literature begins with teacher beliefs, including both classical and current empirical studies. This section is followed by a more specific review of literature on teachers’ beliefs about laboratories. I conclude the following chapter by returning to the importance of the laboratory to science education.
CHAPTER TWO
LITERATURE REVIEW

Science education theory and reform efforts recommend that teachers engage students in learning centered on their own interests and prior knowledge, encouraging them think and act in scientific ways (AAAS, 1990; NRC, 1996; 2000). However, the reality of science classrooms is such that these recommendations are rarely implemented as intended (e.g. Séré, 2002). This study seeks to lessen the divide between theory and practice by examining the beliefs of first-year teachers about laboratories. Through an in-depth study of how first-year science teachers translate their espoused beliefs into classroom actions as they plan for, implement, and assess laboratories, the unique nature of learning to teach science and the realities of science classrooms that act as possible barriers to desirable science teaching are revealed. The knowledge that develops from such a study informs the literature on science education reform in this transition time between preservice teacher education programs and more experienced teaching. In order to better understand the beliefs of the participants in this study, I first provide a foundation from which to build a greater understanding of their beliefs by situating the research in the pertinent literature. In this chapter, I describe the theoretical framework from which I examined the beliefs of three first-year secondary science teachers through a review literature on teacher beliefs, teachers’ beliefs about laboratories, and science laboratories.

Theoretical Framework

Three bodies of literature guided my research, literature on: (a) teacher beliefs, (b) teachers’ beliefs about laboratories in science classrooms, and (c) science laboratories. Because I
am interested in understanding first-year secondary science teachers’ beliefs about the use of laboratories to teach science, these bodies of research informed my data collection and analysis methods and provided insight into the espoused beliefs and classroom actions of the science teachers with which I worked. I begin with literature on teacher beliefs, first defining and then describing pertinent studies that informed the current study. I then investigate the literature on science teachers’ beliefs about laboratories. I conclude by examining literature on science laboratories.

**Teacher Beliefs**

Research summaries of teachers’ beliefs by Gess-Newsome (2003), Kagan (1992), Nespor (1987), and Pajares (1992), as well as research on teacher thinking by Clark and Peterson (1986) and on the role of attitudes and beliefs in teaching by Richardson (1996) were helpful in developing my understanding of the construct of teachers’ beliefs. Reviews and analyses of the literature resulted in an understanding of beliefs as psychological concepts that arise from experience and tend to be episodic in nature (Gess-Newsome, 2003; Nespor, 1987; Richardson, 1996). Beliefs are stable and resistant to change (Gess-Newsome, 2003; Kagan, 1992; Nespor, 1987; Pajares, 1992; Richardson, 1996), and act as lenses or filters through which events are viewed and organized (Gess-Newsome, 2003; Hollingsworth, 1989; Kagan, 1992). Smith (1994) defines beliefs as convictions of a statement’s truth despite contradictory evidence. Teachers’ beliefs are deeply held and influential (Gess-Newsome, 2003; Kagan, 1992; Nespor, 1987; Pajares, 1992; Richardson, 1996) and as a result of years of classroom experiences as students, are well-established in prospective teachers prior to enrollment in teacher education programs (Kagan, 1992; Lortie, 1975; Nespor 1987; Pajares, 1992; Richardson, 1996). Despite their highly
personal and tacit nature, teachers’ beliefs hold great potential for revealing why teachers plan and teach the way they do (Clark & Lampert, 1986; Nespor, 1987; Richardson, 1996).

In 1974, Panel 6 of the National Institute of Education’s National Conference on Studies in Teaching argued that to understand what is uniquely human about teaching, research must be pursued on teacher thinking (as cited in Clark & Peterson, 1986). The panelists suggested that studying the ways that teachers perceive and define their professional experiences is vital to understanding, predicting, and influencing what teachers do. Science teacher thinking has been described in science education research by several constructs; included among those constructs are beliefs.

Anthropologists, social psychologists, and philosophers consider beliefs to be psychologically held understandings that are accepted as true by the believer (Richardson, 1996). Kagan (1992) narrows the definition of beliefs to those specifically held by teachers, broadly defined as assumptions about students, classrooms, and content. Eisenhart, Shrum, Harding, and Cuthbert (1988) state that beliefs are ways to describe relationships between tasks, actions, or events, or a person’s attitudes toward those things. Teacher beliefs are integral to teacher thinking and are therefore vital to understanding classrooms.

In addition to their connection of teacher thinking, beliefs have been described with the constructs of attitudes and knowledge. Beliefs, attitudes, and knowledge are often used in the science education literature to mean similar or even the same things. Therefore, while beliefs are the focus of this study, I briefly examine the use of attitudes and knowledge in relation to beliefs. Beliefs and attitudes are thought to form a subset of constructs that define the structure and content of mental states that drive a person’s actions (Lumpe et al., 2000; Richardson, 1996). Beliefs and attitudes are commonly used interchangeably. In fact, Pajares (1992) called attitudes
“beliefs in disguise.” In contrast, beliefs have been called cognitive to delineate them from the more affective attitudes (Fishbein, 1967), and have also been called attitudes “consistently applied to an activity” (Eisenhart et al., 1988). For the purposes of this study, I define attitudes based on the work of Rokeach (1968), as relatively enduring organizations of beliefs that predispose one to respond to objects or situations in consistent ways. Therefore, while not synonymous with beliefs, they are closely related, with attitudes including in their definition an expected action based upon beliefs.

In the science education community there is also contention among those attempting to delineate beliefs and knowledge; like beliefs and attitudes, beliefs and knowledge are often used interchangeably (Kang & Wallace, in press; Southerland, Sinatra, & Matthews, 2001). Southerland et al. (2001) suggested that many educational researchers see knowledge and beliefs as overlapping—both rising from experiences, but with knowledge emanating from more formal, school-based experiences and beliefs from everyday experiences. In addition, they stated that radical constructivists equate knowledge and beliefs, suggesting that both knowledge and beliefs represent what one believes to be true. In their study, Kang and Wallace (in press) also did not separate knowledge from beliefs due to the assertion that both are value-laden products of human constructions. However, Gess-Newsome (2003), while stating that beliefs and knowledge are closely related, delineated several important differences. Among the differences that Gess-Newsome (2003) identified is the emotionally neutral nature of knowledge. Additionally, Gess-Newsome (2003) and Richardson (1996) identified the requirement of agreement by a community of people rather than the belief of truth by an individual as a difference between beliefs and knowledge. Nespor (1987) suggested that knowledge is more affective, evaluative, and malleable than beliefs. The close relationship between beliefs and knowledge can be
identified in Gess-Newsome’s (2003) assertion that the nature of beliefs and knowledge suggests that beliefs act as filters to knowledge acquisition, organization, and retrieval. The interconnection between beliefs and knowledge can be further understood by Gess-Newsome’s suggestion that having or not having knowledge can affect a person’s ability to implement their beliefs. In addition to the assertions of these scholars, analysis of this study’s data revealed occurrences through which the distinction between the two became clearer. For instance, the participants in this study espoused beliefs that they did not enact. In these cases, it became apparent that while they believed in the value of student-centered laboratories, they had not yet developed the knowledge of how to conduct them. Their beliefs were found to be resonant with traditional, didactic teaching because that is what they know. In addition, they did not exhibit knowledge of how students generate understandings through laboratories. Therefore, for the purposes of this study, I define knowledge as separate from, but related to beliefs.

To further understand the importance of beliefs and their role in teaching, I turn now to pertinent literature in teacher education. In 1987, Nespor stated that little attention had been paid to teachers’ beliefs, but by 1990, teacher beliefs were expected to become the most valuable psychological construct to teacher education (Pintrich), especially in science education. Beliefs as a body of literature have gained prominence since then, and are now considered vital to understanding teacher thought, practice, change, and learning to teach (Bryan, 2003; Bryan & Abell, 1999; Keys & Bryan, 2001; Nespor, 1987; Pajares; 1992; Richardson, 1996; Simmons et al., 1999). Teachers’ beliefs are therefore, integral to an appreciation of the complexities of classrooms. However, research shows that teachers’ beliefs often conflict with their classroom actions (Brickhouse, 1990; Brickhouse & Bodner, 1992; Bryan, 2003; Gardiner & Farrangher, 1997; Haney & McArthur, 2002; Haney et al., 1996; Luft, 2001; Simmons et al., 1999; Thomas
et al., 2001; Yerrick et al., 1997) and are “not necessarily consistent with the literature about best practice in teaching” (Lumpe et al., 2000, p. 276). The empirical research that follows examines studies on teacher beliefs.

In a review of the literature, Calderhead (1996) identified five areas in which teachers have been found to hold significant beliefs:

- Beliefs about learners and learning
- Beliefs about teaching
- Beliefs about subject
- Beliefs about learning to teach
- Beliefs about self and the teaching role

From this list, beliefs about teaching and beliefs about subject stand out as central to this study. As defined by Calderhead (1996), beliefs about teaching can be understood as beliefs about the nature and purposes of teaching, while beliefs about subject focus the research on beliefs to the school subject area of interest. Research on teacher beliefs broadly includes studies in all areas of education. I focus primarily on science teachers’ beliefs due to the nature of laboratories as unique to science classrooms. I begin with studies on preservice teachers and move toward the beliefs of more experienced teachers.

Studies of preservice teachers reveal where beliefs are developed and challenged. Twenty-seven elementary education majors in their first elementary science methods course were the subject of a study by Thomas et al. (2001) which sought to provide participants with “a reflective opportunity to (a) picture themselves as elementary science teachers, (b) place themselves along a teaching theory continuum, and (c) consider the ways in which they developed their own science teaching beliefs” (p. 298). Using the Draw-a-Science-Teacher-Test
Checklist (DASTT-C), participants in the study drew themselves as science teachers and included a brief narrative to support their drawing. A majority of the drawings fell into two distinct groups characterized by Thomas et al. (2001) as teacher-centered and student-centered. They described the teacher-centered drawings as those in which the teacher was either the only person drawn or drawn prominently at the front of the class with backs of the students’ heads visible. They stated that it was often difficult to find the teacher in these student-centered drawings. Thomas et al. (2001) concluded from this study that “preservice teachers’ mental models and beliefs are highly correlated with specific, intense memories of the students’ own science learning experiences in elementary, high school, and college science courses” (p. 303). They suggested that the process of engaging in the DASTT-C provided opportunities for students to explore and reflect on their mental models and beliefs of elementary science teaching. Additionally, they stated that preservice teachers might possess perceptions of themselves as teachers that they do not enact in their classrooms.

In a longitudinal case study of a prospective elementary science teacher, Bryan (2003) investigated beliefs about science teaching and learning through observations, videotaping, and interviews. Throughout a one year study that included a sixteen-week elementary science methods course grounded in a reflection orientation and student teaching, Barbara was found to have beliefs that consisted of three foundational and three dualistic beliefs. Her foundational beliefs consisted of beliefs about the value of science and science teaching, beliefs about the nature of science and goals of science instruction, and beliefs about control in the science classroom. Like participants in Thomas et al.’s (2001) study, prior science learning experiences influenced Barbara. Her foundational beliefs were consistent with her positive science learning experiences, didactic in orientation, and focused on control of procedure and social behavior
respectively. Her dualistic beliefs about how children learn science and the roles of the students and teachers in science instruction formed two contradictory nests of beliefs. Barbara’s conflicting nests of beliefs represented two ends of a continuum which she vacillated between—teacher-centered beliefs that guided her practice and student-centered beliefs that guided her vision of practice.

Preservice teachers like Barbara, have been students for many years, internalizing many of their teachers’ values, beliefs, and practices, through an apprenticeship of observation (Lortie, 1975). As a result of their classroom experiences, when engaged in teacher education programs, they often fail to understand the importance of identifying and confronting their beliefs (Stuart & Thurlow, 2000). Barbara confronted her beliefs, and throughout the course of Bryan’s (2003) study Barbara began to align her student-centered actions with her teacher-centered vision. However, most pre-service teachers do not have the unique opportunity to engage in intensive study of their beliefs while learning to teach.

Interested in how a group of utilitarian preservice teachers would respond to a methods class that focused “explicitly on the relationship between teacher beliefs and classroom practice” (p. 114), Stuart and Thurlow (2000) studied twenty-six pre-service mathematics teachers during a thirteen-week methods course. The students met in the college classroom for the first two-and-a-half weeks and split the next seven weeks between on-campus classes (two days per week) and on-site observations of public school classrooms (two days per week). Stuart and Thurlow (2000) collected interview, journal, autobiographical, and final examination data. By identifying and challenging their beliefs, the participants in this study came to realize that it was possible to hold beliefs about mathematics. Through on-site immersion in real classrooms, they were able to “emotionally connect to a personalized vision of what their classroom could be” (p. 117). Prior
to this study, many of the participants held positivistic views of mathematics that made no concession for holding beliefs about mathematics. Recognizing that they could hold beliefs about mathematics was a realization that Stuart and Thurlow (2000) felt was important to the participant’s growing understanding of themselves as teachers. Stuart and Thurlow (2000) found that differences in beliefs could be attributed to the students’ varied prior experiences in mathematics.

In another study of preservice secondary science teachers’ beliefs, Haney and McArthur (2002) conducted case studies to examine beliefs about constructivist teaching practices. By using pre- and posttest scores on the Classroom Learning Environment Survey, Haney and McArthur (2002) purposefully sampled four preservice teachers for further study. Ross was found to have the lowest pre- and posttest constructivist beliefs; Phoebe and Cliff, the highest; and Audrey had the greatest pre-post change in constructivist beliefs. Through interviews, classroom observations, and document analysis, Haney and McArthur (2002) found that all four participants held central beliefs that dictated subsequent teaching practices and peripheral beliefs which were stated but not operationalized. Ross identified himself through the metaphor of “teacher as efficient manager”. Phoebe chose “teacher as motivator” to describe her beliefs. Cliff selected “teacher as tour guide” and Audrey chose “teacher as resource”. Each participant was able to operationalize the core beliefs of student negotiation, scientific uncertainty, and personal relevance; however, they failed to do so with the peripheral belief of shared control. This failure was attributed to their roles as novice teachers who may not have had the confidence to take the risk of sharing control with their students (Haney & McArthur, 2002). Haney and McArthur found this particularly troubling in the current environment of high stakes tests in which teachers feel pressure to cover the content and therefore, often forfeit constructivist ideas like shared
control. Their study suggests that despite desires to implement constructivist pedagogies, core beliefs that contradict such pedagogies act as barriers to their realization.

Beginning teachers were the participants in Simmons et al. (1999) in-depth longitudinal study of the role of science teachers’ beliefs and actions. Simmons et al. (1999) analyzed data from 116 beginning teachers, ninety-eight of whom were secondary science teachers. Through interviews, observations, and a survey instruments, Simmons et al. (1999) found that most participants espoused teacher centrism or held beliefs about content and process that “wobbled.” This pattern decreased in the second and third years of teaching. As teacher-centered beliefs declined between their first and third years, most of the teachers wobbled in their beliefs about their teaching roles. These teachers also wobbled in their beliefs about what students should be doing, with slightly more teachers holding more teacher-centered beliefs by their third year.

First-year teachers in this study viewed themselves as student-centered, but were observed to be teacher-centered in their classroom actions. Additionally, participants were found to be more reflective about teaching and learning when given the opportunity to explain their beliefs. Simmons et al. (1999) concluded that in order to affect change, we need to “rethink how we come to understand and how to act on that understanding” (p. 949).

Beginning and experienced teachers face similar conflicts in their beliefs. Luft (2001) examined the beliefs and practices of secondary science teachers participating in an eighteen-month in-service program, using structured and semistructured interviews and classroom observations. The Inquiry-Based Demonstration Classroom (IBDC) was used as the professional development model for this study and began with a six-day preprogram, followed by a one-day workshop aimed at orienting the teachers to inquiry-based science instruction. Participants then took part in an extensive five-day workshop in which they “explored, experienced, and processed
an extended inquiry cycle while also developing an extended inquiry cycle to enact in their
classrooms” (Luft, 2001, p. 519). Four additional opportunities, whose purpose was maximizing
their time with each other and the IBDC staff, followed. All participants identified inquiry
instruction as important to science teaching; although, only six indicated using any type of
inquiry in their classrooms. Six of the fourteen participants were beginning teachers and were
shown to have changed their beliefs more than their practices during the period of this study.
These beginning teachers were slightly less likely to implement extended inquiry cycles than the
veteran teachers. The eight veteran teachers changed their practices more than their beliefs—five
of whom implemented three or more extended inquiry cycles. The beliefs and practices of the
beginning teachers in this study eventually aligned—toward student-centered and more
traditional instruction. Luft (2001) concluded from this study that induction teachers should be
supported beyond their first-year teaching due to the pliable nature of their beliefs.

For experienced teachers, the number of years of teaching experience positively
correlated with beliefs in a study by Lumpe et al. (2000). Lumpe et al. (2000) interviewed 130
purposely selected teachers regarding environmental factors and/or people who influenced their
science teaching in order to prepare a survey instrument on science teachers’ beliefs (Context
Beliefs About Teaching Science Instrument). This instrument was used with 262 teachers to
determine their context beliefs about science teaching. For the purposes of their study, Lumpe et
al. used context beliefs to refer to the teachers’ perceptions of control. Context beliefs were
found to positively correlate with years teaching and to the number of undergraduate science
methods courses taken by participants. As a result of this study, Lumpe et al. (2000) suggested
that while teachers are change agents in educational reforms, teacher beliefs are “the more
precise agents of change” (p. 288). They recommend professional development and support structures that focus on context beliefs.

Haney et al. (1996) conducted a study of 800 experienced teachers to investigate their beliefs regarding the implementation of science education reform strands. A structured interview and questionnaire were constructed to examine participants’ beliefs. Thirteen teachers participated in the structured interviews from which the questionnaires were developed and mailed to the 800. Haney et al.’s (1996) findings suggest that both the obstacles and enablers that their participants faced were seen as less important than their beliefs about the expected outcomes associated with their behaviors. Using beliefs and attitudes interchangeably, they recommended that teacher training pay particular attention to teachers’ attitudes toward behavior “before alterations of the control factors (such as providing curriculum materials, reducing class size, including flexible class scheduling, etc.)” (p. 985). They concluded that top-down “teacher-proof” models of reform that fail to attend to teachers’ beliefs are unlikely to meet with success, and suggested instead concrete teacher training in which teachers experience success, observe success, are persuaded with messages aimed at addressing positive and negative beliefs, and engage in positive emotional tone when describing their experiences. They also recommend support from principals, local media, and the community as vital to the success of valuing teachers’ beliefs and implementing reforms (Haney et al., 1996).

In summary, several studies point to the importance of studying teachers’ beliefs for understanding science classrooms. Prior experiences as science learners and science teachers, as well as the number of science methods courses taken all were shown to affect teachers’ beliefs. As a result of these experiences, science teachers often hold stable core beliefs about science teaching and learning and fail to recognize the importance of identifying and confronting those
beliefs. Core beliefs have the added effect acting as barriers to the establishment of newer, more pliable beliefs. The stability of these core beliefs, which are typically more teacher-centered as the result of experiences as students in teacher-centered science and science methods courses, have been shown to affect a mismatch between teachers’ espoused beliefs and those that they enact in their classrooms. Additionally, salient core beliefs often overshadow reform-based beliefs which science teacher education and reform initiatives attempt to instill. In the cases of Bryan (2003) and Simmons et al.’s (1999) studies, opportunities to confront and explain beliefs led participants to become more reflective about the beliefs that they held, resulting in the establishment of newer beliefs.

*Science Teachers’ Beliefs About Laboratories*

A second body of research that guided my study was literature on science teachers’ beliefs about laboratories. Research on teacher beliefs about laboratories is often situated in studies about science teacher thinking and beliefs, but because the laboratory is central to science teaching, this research also addresses many of the issues that science teachers encounter when teaching in the laboratory. In fact, a review of the literature by Hofstein and Lunetta (1982) revealed that the goals and objectives for science learning in general and laboratory learning more specifically were largely synonymous.

Laboratories are the most distinctive feature of science instruction (Shulman & Tamir, 1973). However, in 1989, Tamir reported that very few science teacher education programs “offer direct systematic instruction on how to teach in the laboratory” (p. 60), often assuming that experiences in college laboratories prepare them for teaching via laboratories. As a result, many science teachers do not perceive any potential value for laboratory learning. In fact, Tamir (1989) reported that teachers often take laboratory exercises from commercial textbooks without
consideration of their nature or potential for student learning, resulting laboratories as mindless exercises (White, 1996). Therefore, many teachers do not engage students in ways that might promote such meaningful learning in the laboratory (Hofstein & Lunetta, 2003). For instance, in research by Gardiner and Farrangher (1997) the biology teachers that they studied espoused teaching philosophies that supported investigative, authentic learning experiences, but their classroom practices were not generally consistent. Even teachers convinced of the value of labs often do not implement them in ways that facilitate planned learning, necessitating a focus on designing and implementing lab investigations in science teacher education programs (Tobin, 1986).

The key to effective learning in the science laboratory is the teacher (Beck, Czerniak & Lumpe, 2000; Bybee, 2000; Chiappetta, Koballa, & Collette, 1998; Levitt, 2002; Tamir, 1989). Understanding the roles that teachers play in the lab is vital to gaining insight into implementing changes there. Like Schwab (1962), Beck et al. (2000), Chiappetta, Koballa, and Collette (1998), and Levitt (2002) among others, point to the teacher for the ultimate success of lab work, since it is the teacher who makes decisions regarding what labs, skills, and content are important, when and how long labs should be used in the science curriculum, and the purpose of labs in their classroom. In fact, what value teachers place on content often determines what content is taught (Pajares, 1992). The empirical research on teachers’ beliefs about laboratories that follows begins with preservice and moves to more experienced teachers.

Preservice teachers’ beliefs about laboratories can be influenced through reform-based teacher preparation programs. The attitudes and beliefs of preservice mathematics and science teachers were examined by McGinnis, Kramer, Shama, Graeber, Parker, and Watanabe (2002). Specifically, McGinnis et al. (2002) measured the evolution in attitudes and beliefs over the
course of a reform-based semester. Participants in this study consisted of a group who were part of the Maryland Collaborative for Teacher Preparation (MCTP) and planned to become specialist mathematics and science upper elementary or middle grade teachers and a non-MCTP group or preservice mathematics and science teachers. The survey instrument employed was repeated several times over the course of the study and included statements such as “getting the correct answer to a problem in the science classroom is more important than investigating the problem in a scientific manner” and “students should be given regular opportunities to think about what they have learned in the science classroom” (p.732). McGinnis et al. (2002) found that over the two-and-a-half years that the study was conducted, the attitudes and beliefs of the MCTP group were in line with those desired by the MCTP program. They also found significant differences between the attitudes and beliefs of the MCTP and non-MCTP groups toward desirable mathematics and science teaching, but were particularly struck by the decline in sub-scale scores of the non-MCTP participants after taking MCTP courses. They suggested that this pattern was due to the unintended effect that reform-based instruction could have on non-reform-oriented students.

In addition to reform-based teacher education programs, engaging in independent inquiry experiences can affect preservice teachers’ conceptions of laboratories. In a study by Windschitl (2003), six secondary preservice teachers in a science methods course were observed during a two-month inquiry project and a nine-week teacher practicum. The first two weeks of the project were designed to “help students understand science as a way of knowing the world and finding out what scientists actually do” (p. 118). During the study, participants kept a reflective journal to document their “journey”. Three of the participants used guided inquiry regularly and open inquiry, less frequently. One participant used guided inquiry once and no other forms of inquiry.
The final two participants did not use inquiry at all in their classrooms. Windschitl (2003) found that the participants in this study who used guided and open inquiry during student teaching were those that had significant authentic science research experiences, rather than those that expressed more genuine views of inquiry learning. As a result of this study, Windschitl (2003) advocated scaffolded, independent science investigation as part of preservice education programs that reflect the nature of inquiry, stating that “preservice teachers desperately need such experiences (p. 116). Additionally, he suggested that these experiences must include conceptually linked ways to incorporate inquiry in classrooms.

“Beginning teachers have translated their experiential worlds of the classroom into a unique view of what constitutes good teaching and learning, and they define their philosophy of teaching based of these beliefs and experiences” (Simmons et al., 1999). Evidenced in research on beginning teacher is the contrast between what beginning teachers want to accomplish, based on their experiences and views of good teaching and learning, and what they are capable of accomplishing (Lederman, 1999); dreams versus reality. Luft and Patterson (2002) studied 13, 17, and 21 beginning science teachers over three traditional nine-month school years through a program called ASIST (Alternative Support for Induction Science Teachers) in an effort to investigate induction programs and reform. The participants in this study had ongoing support through monthly meetings, communicated electronically, traveled to a state or national conference, and were observed teaching. Participants were encouraged to use inquiry investigations throughout the study. The findings from this study suggest that such support improved the participants’ ability to use inquiry in their classrooms. Participants also reported greater confidence in teaching science. Seventy-five percent of the participants stated that the ASIST program significantly challenged their ideologies about science teaching (Luft &
Patterson, 2002). Additionally, the research component of the study focused on the relationship of the participants’ beliefs to their classroom practice. As a result of this study, Luft and Patterson (2002) suggested that beginning teachers hold pliable beliefs that can be refined through the influence of induction programs toward reform-based ideas.

Many beginning teachers espouse student-centered beliefs about teaching and learning, but their actions often prove incongruent with those beliefs (e.g. Bryan, 2003). This is frequently due to their focus on classroom management (Brickhouse, 1990; Lederman, 1999) and fact acquisition (Brickhouse, 1990). Beginning teachers also rely more heavily on textbooks and procedures in an effort to find support in structure (Brickhouse, 1990). For teachers focused on the factual and procedural, the likelihood that teacher-centered approaches like lecture and reliance on textbooks will be used is high, making the likelihood of student-centered laboratory use low. For example, McGee, a first-year teacher studied by Brickhouse and Bodner, espoused both student-centered and teacher-centered beliefs, but enacted primarily teacher-centered pedagogies (1992). Science, as enacted in McGee’s classroom, was much more formal and structured than his espoused beliefs suggested, resulting in conflict between his beliefs and his practice, and reducing his laboratory use to factual acquisition exercises. In 1990, Brickhouse reported on McGee in his second-year teaching, who like most beginning teachers, relied on the textbook as the authority, and sought necessary structure through the use of the scientific method, expecting his students to learn through the accumulation of facts. Missing in McGee’s beliefs about science teaching was the view that science is revisionary, rather than accretionary.

Beginning teachers are not alone in their struggles to bring their student-centered beliefs into concert with more teacher-centered actions in the science laboratory; many experienced teachers face these same challenges. Research suggests that with experience, teachers tend to
become less reliant on structure, management, and didactic teaching methods; however, as teachers in a study reported by Simmons et al. gained experience, their classroom actions became more teacher-centered (1999). Therefore, the struggle to translate student-centered beliefs into laboratory classroom action proves challenging for teachers with experience as well.

In a study whose focus was promoting deeply rooted change in science classrooms Yerrick et al. (1997) found traditional, experienced teachers who assimilated reforms into their student-centered beliefs. Yerrick et al. (1997) investigated the beliefs and interpretations of experienced teachers in a two-week summer institute. The purpose of the institute was to change their treatment of scientific knowledge and their assessment strategies. Eight of the twenty-four teachers who participated in the two-week summer institute, took part in pre- and post-institute interviews. The average teaching experience of the institute participants was eight years. Yerrick et al. (1997) found that participants entered the institute with the belief that teaching science meant teaching long lists of facts. Additionally, they found that their participants failed to take their students into consideration when deciding what and how to teach, viewing them only as recipients of knowledge (1997). They reported that their participants’ beliefs “were not representative of current reform expectations or current thinking beliefs about science and learning” (p. 154). Based on their findings, Yerrick et al. asserted that teachers found ways to assimilate reforms into their beliefs even though the reforms were often contradictory to what they originally believed (1997).

The beliefs of the experienced teachers in Tsai’s (2002) study ranged from traditional to constructivist. Tsai (2002) selected thirty-seven Taiwanese secondary school physics and chemistry teachers to participate in their study on science teachers’ beliefs of teaching, learning, and the nature of science. Teaching experience for the participants ranged from two to twenty
years, with an average of seven years. Interviews were the primary means of data collection. The framework that Tsai (2002) used to categorize beliefs separated them into three categories: (a) traditional, “learning science is acquiring or ‘reproducing’ knowledge from credible sources”; (b) process, “learning science is focusing the processes of science or problem-solving procedures”; and (c) constructivist, “learning science is constructing personal understanding” (p. 775). Over half of those interviewed held traditional science teaching and learning beliefs. They also held traditional beliefs about the nature of science. Only four of the thirty-seven participants held constructivist views of the nature of science. A majority of the participants’ beliefs about teaching, learning, and the nature of science were highly related to each other. For instance, only two of the participants had totally divergent beliefs among the categories. Of those that expressed constructivist beliefs, one was considered experienced, while the other was considered in the “most junior science teaching group”, with fewer than four years of experience. Tsai (2002) contributed the findings to possible reinforcement of traditional teaching practices in teacher education programs.

Lavonen (2004) studied ninety-eight inservice physics teachers over the course of a one-and-a-half year inservice training program to determine how the training program affected their beliefs about the role of experiments. The Inservice Training for Physics Teachers (ITPT) program was designed to enhance the participants’ content and pedagogical content knowledge. Through discussions during lectures, seminars, an e-mail list, and permanent local study groups, participants interacted regarding the epistemic role of experiments in physics teaching. Coursework included “Principles of Concept Formation”, “Experiments in School Laboratory”, “The Conceptual and Processual Structures of School Physics”, and “History of Physics”. Following the inservice program, Lavonen (2004) prepared a web-based questionnaire.
Measured before and after the ITPT program, the numbers of demonstrations used did not differ for either the ITPT or the control group. Additionally, both groups conducted practical work approximately every four lessons—a number which did not change following the ITPT. Lavonen (2004) reported no significant difference between the two groups in their use of experiments in teaching. Both groups agreed on the five most important reasons for experiments: “students learn concepts of physics, experiments arouse external motivation, experiments allow hands-on activities, students learn about the nature of physics, and students learn process skills and enjoy increased procedural understanding” (p. 323). Where the ITPT teachers differed was that following the inservice program, they consciously attended to the goals of classroom experiments as means of helping students construct meanings. Additionally, the ITPT teachers reported a slight improvement in their use of experiments, whereas the non-ITPT group did not report improvement.

In another example, an experienced teacher, Marcy, who participated in a study conducted by Cronin-Jones (1991), exhibited teacher-centered beliefs, which included factual content, neatness, and spelling as the most important student outcomes in science learning. Marcy, a nine-year veteran of science teaching, relied heavily on procedural directions and discipline, and believed her students learned best through repeated drill and practice. Shelley, a second participant in Cronin-Jones’ (1991) study, with thirteen years teaching experience, also believed that facts were the most important student outcome of her teaching and relied heavily on drill and practice. Each of these teachers’ beliefs about student outcomes, teaching, and learning in their classrooms led to more teacher-centered environments in which didactic teaching methods were central and not in concert with recommended methods for laboratory learning.
In a case study of an expert urban elementary teacher, King, Shumow, and Lietz (2001) found that teachers were more poorly prepared in the areas of science content knowledge, and instructional, pedagogical, and management skills than expected. The ultimate goal of this study was to develop a set of perspectives that included: the teacher’s, a science education specialist’s, and an educational psychologist’s, from which instruction could be examined. The perspectives that developed from this study suggested that there existed an inconsistency between how the teachers perceived their teaching practice—as student-centered—and the expository nature of the science lessons.

While both experienced teachers in a 1990 study by Brickhouse enacted their views in ways that were consistent with their different educational goals for their students, one espoused student-centered goals and the other did not. One of the two teachers used procedural information to drive laboratory instruction and wanted his students to know the scientific theories; the other wanted her students to use those theories to solve problems, teaching processes and products separately, and encouraging a more student-centered, inquiry-oriented atmosphere. Their views of the role of theories resulted in one group of students being given the opportunity to participate in inductive research laboratories, while the other participated in observation and experimentation as driven by scientific theories.

Not all research on experienced teachers’ beliefs about laboratories suggests that their beliefs are primarily traditional. Kang and Wallace (in press) worked with three veteran teachers, Tom, Pamela, and Jerry to examine their professional knowledge of laboratories. Through group and individual interviews, classroom observations, and document collection, they found that the teachers in their study held different primary goals for their laboratories around which their teaching focused. Their primary goals were student engagement, preparing student to live as
informed citizens, and building scientific habits of mind respectively. These goals showed evidence of development as a result of their teaching experiences, and were framed by their epistemologies, developed as a result of the teachers’ perceptions of their students’ immediate needs, and resulted in unique classroom cultures. For Tom, student creativity and curiosity were enhanced through laboratories. Pamela saw laboratories more as places where lecture materials could be applied. Jerry used laboratories to show his students how well science theories and natural phenomena are aligned.

Jake, an experienced teacher in a study conducted by Crawford (2000), provides another example of a student-centered classroom. Jake situated instruction in his classroom in authentic problems that were meaningful and relevant to his students. He encouraged collaboration and the importance of rigor in data collection and analysis. Jake took on several roles during his teaching that significantly influenced the success of laboratory investigations in his classrooms, including that of innovator, experimenter, researcher, modeler, collaborator, and learner (Crawford, 2000). His case counters Simmons et al.’s findings, that experience results in more teacher-centered behavior, but is possibly explained by Jake’s twelve years of teaching experience versus the three years of experienced reported in Simmons et al.’s study (1999).

Some experienced teachers use student-centered pedagogies, but face barriers to their implementation. Constructivist teachers more frequently used potentially effective teaching strategies than their empiricist colleagues in a study of thirty-five experienced Palestinian teachers of different science backgrounds and at different educational levels (Hashweh, 1996). Through a three-part questionnaire that focused on critical incidences and teaching strategies Hashweh (1996) examined their beliefs about learning and knowledge in teaching, investigating the numbers and types of teaching strategies that participants used. The constructivist
participants used a greater number and variety of teaching strategies and were better prepared to induce student conceptual change. Hashweh (1996) found that teachers’ epistemological beliefs are stable and strongly influential. It is the competence of teachers and their beliefs about the importance of lab work that, regardless of what individual science education reform efforts suggest, controls the degree to which science content and skills, including inquiry skills, are taught.

Constructivist science teaching and learning was also the focus of a study by Beck et al. (2000) who used questionnaires to investigate the beliefs of 203 inservice teachers, with an average of sixteen years teaching experience. One questionnaire was open-ended and five follow-up questionnaires focused separately on teacher intent, scientific uncertainty, critical voice, shared control, and student negotiation—the five components of constructivist learning. The teachers in this study believed that they should teach for personal relevance, but found barriers in the form of extended time for preparation and a shortened length of time to cover content. They also believed that teaching scientific uncertainty can show students the limitations of science; however, barriers arose to these beliefs as well, in the form of preparation time and classroom management. Most of the teachers held positive attitudes about using critical voice in their classrooms, believing that it helped their students take responsibility for their learning. Shared control was another area where most of the participants held positive attitudes. In contrast to Haney and McArthur’s (2002) study, the experience of the teachers in this study may have supported their beliefs about shared control. Under the category of student negotiation, the participants believed that students learn communication and higher-order thinking skills through constructivist lessons. Additionally, through student negotiation, the teachers believed that students’ interest in science would improve. They identified classroom management as a barrier
in this area. Beck et al. (2000) concluded that in order to foster positive attitudes and beliefs towards science teaching, staff development should be long term, focus on beliefs, and involve teachers in positive experiences in which constructivist teaching is modeled. They also stated that lack of planning and class time were significant concerns of the participants in their study and were identified as barriers to constructivist teaching.

In summary, teachers are central to the success of laboratories and research on teachers’ beliefs about laboratories points to some striking similarities between beginning and experienced teachers. Most striking is that most beginning and experienced teachers espouse student-centered beliefs, but enact teacher-centered methods. Induction support appeared to improve beginning teachers’ use of inquiry, and reform-based inservice courses positively affected teachers’ beliefs about reform. However, traditional beliefs held on as salient to most of the teachers studied. Barriers to implementing student-centered laboratories were similar for both groups as well; however, more experience resulted in greater use of constructivist teaching and learning strategies.

*Science Laboratories*

A third body of research that informed this study was literature on science laboratories. My definition of laboratories is informed by guidelines set out by the AAAS (1990) and the NRC (1996; 2000) as well as literature by Chiappetta, Koballa, and Collette (1998), Hofstein & Lunetta (2003), Lunetta (1998), and Tamir (1977). Reviews and analyses of the literature have resulted in an understanding of laboratories as opportunities for students to investigate scientific phenomena through the asking and answering of questions of interest to them, while generating hypotheses and patterns, collecting evidence, and discussing and communicating their results. Laboratories are experiences in school settings that encourage the interaction of students with
materials, in an effort to observe and understand the natural world (Lunetta, 1998; Lunetta & Tamir, 1979; Schwab, 1962). Laboratory use ranges from verification of teacher-“known” scientific results to inductive, inquiry-oriented activities in which students generate patterns and gather data while investigating topics of interest to them (Lunetta, 1998). Tamir (1977) includes verification and discovery activities in his understanding of laboratories. Verification laboratories are more common (Roth et al., 1997). In fact, classroom laboratory experiences traditionally follow lectures to reinforce content taught, utilizing teacher-centered approaches that tend to ignore students’ prior knowledge and cultural understandings, while attempting to teach massive amounts of facts with little effort at making connections (Roth et al., 1997).

The laboratory is integral to any science program (Scotti, 1989; Séré, 2002). Laboratories have been used in science teaching for over a century and are unique and demanding places for teaching science. They are viewed as essential components of science classrooms (Kang & Wallace, in press; Tobin, 1990) and hold promise for problem solving and the construction of relevant science knowledge (Tobin, 1990). Laboratory activities appeal as a way of engaging students in opportunities to experience science in a direct way. Ideally, with this direct experience, as well as time to reflect, think, and make sense of their actions, students involved in laboratories can engage in constructing knowledge. Yet, to date, laboratories have failed to meet their potential for meaningful science learning. The concerns of those who acknowledge the failure of science laboratories are not unique to the twenty-first century; however, today’s contemporary teaching standards burden teachers, many of whom “do not utilize or manage the unique environment of the school laboratory effectively” (Hofstein & Lunetta, 2003).

**Goals and purposes of laboratories.** According to Hofstein and Lunetta (2003), for more than one hundred years, laboratories have been purported to promote the following goals:
• Understanding of scientific concepts
• Interest and motivation
• Scientific practical skills and problem solving abilities
• Scientific habits of mind (more recent)
• Understanding the nature of science (more recent).

In addition, over the last century, laboratories have trained students in observation, supplied them with detailed information, and aroused their interest in science (Blosser, 1983). These goals are supported today as evidenced in science education research and national science education policy; although, the effectiveness of labs towards reaching these goals has not yet been demonstrated (Kang & Wallace, in press; Tobin, 1990).

With the goals for science laboratories in mind, I examine two sources for defining the purposes of laboratories that undergird this study. The national science education reform efforts and the teachers themselves are two primary sources that define the goals and purposes of laboratories for science teachers. Additionally, research in science classrooms has much to say on this topic. National reform efforts (AAAS, 1990; NRC, 1996; 2000) recommend that science teachers enculturate all students into authentic science practice through questions and topics generated from the students’ own experiences. There is clearly value placed on learning science in the laboratory at the national policy level. In addition, research has acknowledged this value attribution and continued for the most part to support it (Hofstein & Lunetta, 1982), even in the face of contradictory evidence.

There exists limited evidence that the suggestions made by national science education reforms are being successfully implemented in science classrooms because, as Gess-Newsome stated, “few classroom teachers…hold even a cursory level of understanding about the
Standards, much less an in-depth comprehension and vision for what implementation of the Standards with fidelity into classroom practice would entail” (2003, p. 28). Therefore, teachers convinced of the value of laboratories often do not implement them in ways that facilitate planned learning, necessitating a focus on designing and implementing laboratory investigations in science teacher education programs (Tobin, 1986). This may be because, as Tobin suggests, “at the present time, most teachers do not understand the role of laboratory activities as a means of allowing students to solve problems and thereby construct knowledge of science. Verification laboratories are common and usually take the form of cookbook activities. To change the type of activity encountered in the laboratory will necessitate a change in the culture of the science classroom.” (1990, p. 415)

In fact, because of the increased risk of unexpected, unintended, and uncontrollable events often associated with more student-centered learning, teachers tend to be more comfortable with teacher-directed, cookbook labs (Gardner & Gauld as cited in Hodson, 1993a).

In an ethnomethodological study by Roth et al. (1997), designed to describe students’ actions in a traditional physics class, phenomena were frequently constructed by students that were in contrast with accepted science knowledge. As foundational to this research, Roth et al. suggested that interpretation is the result of experiences and existing understandings, causing observations to depend upon what one already knows (1997). This interpretivist perspective led them to investigate the differences between science learning as perceived by students versus that perceived by teachers. They posited that as a result of these differences in perception, discovery learning in science laboratories is virtually impossible. The teacher’s goals for learning from laboratories in this study were not self-evident to the students, nor were they necessarily what the
teacher intended the students to learn. Students in this study were unable to assess how their actions failed to conform to their teacher’s instructions, leading Roth et al. (1997) to conclude that “to see what the teacher wants students to see and to do what the teacher wants students to do, students already need to know what they are supposed to learn” (p. 133). They suggested that addressing this gap requires class discussions which focus on the diversity of views within the classroom and as contrasted to accepted scientific knowledge, as well as laboratories in which students choose the problem that they are interested in examining and are assessed on the degree to which process and products are aligned. Their assertions are supported by Driver (1988) who stated that students’ understandings toward accepted science require the intervention of and negotiation with an authority. This is also supported by the National Science Education Standards (NRC, 1996) as a means of constructing and evaluating alternative explanations. The goal is the manipulation of ideas rather than simply materials since engaging in scientific argumentation aids in the meaningful construction of student knowledge (Hofstein & Lunetta, 2003).

Research suggests many additional reasons for the inability of labs to meet intended goals. Among them, cognitive overload of students’ recall (Wham, 1982), and dull, teacher-directed aspects of laboratories leading to failure of students to make connections with other learning (Hodson, 1990). In a study of the science classrooms of fifteen Australian secondary teachers, Tobin and Gallagher (1987) found that participants defined the most effective learning activities in terms of “clear and logical explanations of content”, suggesting an emphasis on a teacher-centered, lecture-based model. Not surprisingly, these same teachers viewed their curriculums in terms of content to be covered and defined success of their lessons by student test
achievement. This finding points strongly to the realities of the science classroom being in contrast with the intended purposes of laboratory learning.

Ultimately, the purposes for teachers use of laboratories depends moderately upon the type of laboratory, but tend to be similar from teacher to teacher and include teaching independent thinking (Haney et al., 1996; Kang & Wallace, in press; Wallace & Kang, in press), critical thinking and problem solving skills (Tobin, 1990), having fun (Brickhouse & Bodner, 1992; Kang & Wallace, in press; Tobin, 1986), and preparing students for the “real world” (Crawford, 2000; Kang & Wallace, in press; Tobin, 1986). Where purposes for laboratories differ are in teachers’ use of cookbook laboratories as primary tools for verification of expository lessons (Wallace & Kang, in press; Lunetta, 1998; Tamir, 1977).

In addition to the goals and purposes of laboratories set forth by teachers and policy makers, many science education researchers have engaged in discussions about their purposes. For instance, in separate chapters from Which Way Now?, a book that examined the place of practical work in science teaching, Wellington, Woolnough, Hodson, and Millar (1998) discussed the purposes of laboratory learning and the role of cookbook laboratories in the curriculum. Wellington posited that the purpose of laboratory work was to convey the nature of science, pointing out that science processes cannot be separated from content. Therefore, getting a feel for apparatuses and phenomena as well as developing scientific knowledge, attitudes, and skills via genuine inquiry projects were purposes for labs. In contrast, Woolnough stated that laboratory work was most effective for teaching practical problem solving skills and personally usefully knowledge, adding that school laboratories can provide a sense of achievement, making laboratory learning more meaningful. Woolnough separated teaching the what and the how of science, recommending open-ended problems to be solved. Hodson focused on the messiness of
science and laboratory learning’s value, stating that there is no scientific method and that the key elements of this type of learning are apprenticeship and the opportunity to change one’s mind. Millar suggested that laboratory work is most effective with the teacher as a guide as students develop knowledge and understanding through purposeful, autonomous action via practical, scaffolded tasks. This discussion of the purposes of laboratory work is important in that, while the four authors disagree on the specific purposes of laboratories, they broaden the current discussion of what exactly laboratories are and what they are intended to be.

With these arguments for and against laboratory work in mind, I turn to empirical studies that have examined laboratories. In a review of seventy-five laboratory instruction sheets for secondary laboratories from five countries and ninety from university laboratories in six countries, Tiberghien, Veillard, Maréchal, and Buty (2001) investigated the similarities and differences in laboratory tasks. Labsheets were chosen as the subject of study due to their “ubiquity in practice and...key roles in guiding students’ actions and learning” (Tiberghien et al., 2001, p. 489). They found that across educational levels, science subjects, and countries, labwork was similar. At the secondary level, student identification of phenomena and familiarization with them was common across disciplines. Planning and conducting investigations, on the other hand, was not common in all disciplines. At all levels, students were expected to observe and measure. In all countries and disciplines, the single source of information for the laboratory comes from material objects inside the laboratory. At the secondary level “students often have to make direct reports of observations, but they do not often have to present or display or make an object. They seldom have to explore relationships between objects, test a prediction, choose between two (or more) explanations, or invent a new concept (or entity)” (Tiberghien et al., 2001, p. 502). Tiberghien et al. (2001) concluded their study with a statement suggesting that there is “an
implicit international paradigm of labwork in science education” (p.503), which has been discussed above in terms of the rarity of student-centered/driven laboratory experiences.

In order for laboratory learning to be meaningful, teachers and students must be explicit about their purposes for engaging in laboratories (Hofstein & Lunetta, 2003). One classroom in which the teacher’s purposes and her students’ learning were successfully tied together was reported by Hart, Mulhall, Berry, Loughran, and Gunstone (2000). They examined the aims and purposes that the teacher, Christina, had for a science unit and her students’ understanding of those purposes. They posited that if students understood their teacher’s specific intended learning outcomes (aims) and her pedagogical intentions (purposes) they would make better sense of what they were doing in the laboratory. By doing so, they sought to address this one aspect of the failure of laboratories to result in meaningful student learning and found that “while research has generally shown that laboratory work is not always a useful strategy for teaching science knowledge…it can be used for other purposes” (p. 672). In this study, Christina’s purpose was to develop her students’ understanding of the development of scientific facts via experimental work, focusing specifically on communication and replication as important factors. However, it is often not the case that the specific purposes for laboratory work are often made explicit, resulting in students’ own perceptions of the purposes as either following directions or getting the right answer (Hofstein & Lunetta, 2003). In these cases, there is often a failure by students to make connections with earlier work or to understand discrepancies between their understandings and those of their peers, teacher or scientists (Hofstein & Lunetta, 2003).

Stating that few studies on laboratories have used qualitative methodologies to examine teacher perceptions, attitudes, behaviors, and instructional practices, DeCarlo and Rubba (1994) investigated the behaviors of three high school chemistry teachers, using a systematic
observation instrument and fieldnotes. Their participants’ behaviors were coded by the following descriptors: “fetching” materials for use in the lab, “observing” students without interaction, “directing” student behavior, “stimulating” student thinking, “socializing”, and being “unengaged”. Ms. Whalen’s behaviors were most often categorized as highly interactive and involved telling her student what to do and how to do it and socializing. Mr. Allen’s behaviors were somewhat socially interactive, but primarily unengaged. Mr. Roger’s behaviors were categories as highly non-interactive. For both Ms. Whalen and Mr. Allen, it appeared that teacher behavior and student behavior were positively related. Mr. Roger’s students on-the-other-hand, displayed on-task behavior even though he was unengaged. In all three cases, on-task behavior from the students was greatest when the teacher circulated in the room. DeCarlo and Rubba (1994) call for an “examination of teacher and student beliefs, behaviors, attitudes, and perceptions regarding laboratory activities” (p. 47) in order to address the inconsistencies in their findings and the myriad of variables inherent in laboratory teaching.

Learning in the science laboratory has been shown successful when discussion and reflection are pivotal to the laboratory learning environment; however, such opportunities are rare since students are often involved in the technical rather than metacognitive activities of laboratory learning (Gunstone & Champagne, 1990). Studies have shown that teachers and students are often preoccupied with technical and manipulative details, thereby limiting the potential of laboratory work by focusing attention away from opportunities for genuine student-interaction and reflection (Champagne, 1990). Tobin supported and extended this view by suggesting that “the crucial ingredient for meaningful learning in laboratory activities is to provide for each student opportunities to reflect on findings, clarify understanding and misunderstandings with peers, and consult a range of resources which include other students, the
teacher, and book and materials” (1990, p. 414). He continued by saying that the teacher in such a classroom should maintain a classroom in which students are challenged and doing science with assistance if needed.

In addition to research on teachers, student attitudes and interest in science, as central to the success of laboratory work, are deeply rooted in the science education literature (Hofstein & Lunetta, 2003). As motivation for learning, laboratories have the potential to increase student interest, and as Hofstein and Lunetta (2003) stated, the lack of data in the affective domain is especially unfortunate in a time when greater emphasis is being placed on the needs of women and underrepresented minorities in the sciences (2003). Hofstein and Lunetta (1982) and Lazarowitz and Tamir (1994) suggest that attitudes and cognitive growth can both be enhanced through laboratory learning. In addition to student attitudes and interest in science, more informal and social aspects of laboratory learning “can promote positive social interactions and a healthy learning environment conducive to meaningful inquiry and collaborative learning” (Hofstein & Lunetta, 2003, p. 36). Teachers find tailoring laboratory activities to their students’ diverse needs especially challenging. Suggestions to address this problem include small group collaboration and independent inquiry, which many teachers are not prepared to do. This community-of-scientists atmosphere contributes to students’ problem solving and knowledge development as well as their understandings about the nature of science.

In summary, laboratories are integral to science classrooms and are the way that reform-based initiatives can best be implemented. Teachers believe that laboratories are useful for teaching independent, critical thinking and problem solving skills, as well as improving student attitudes towards science. Teaching scientific facts through communication and replication is also an important goal of laboratories for teachers. However, in order for laboratories to meet
intended goals, both teachers and students need to know explicitly the purpose for each
laboratory. In addition, discussion and reflection in combination with laboratories is pivotal to
their success. Research shows that laboratory success faces many barriers in the form of
including preoccupation with technical and manipulative details, classroom management, and
control. These barriers, coupled with research on teachers’ beliefs about laboratories suggest that
to date, reforms are failing to affect science classrooms in any significant way.

Rethinking the Role and Practice of Laboratories

While there is extensive literature on teachers’ beliefs and science laboratories, including
the importance of inquiry-based teaching and learning, there is little known specifically about the
beliefs of first-year secondary teachers regarding the use of laboratories for teaching science. The
mismatch between science education theory and reform as taught in science teacher education
programs, and teacher beliefs about and implementation of laboratories makes for a rich area of
study. This time between teacher education programs and experienced teaching is essential for
the establishment of sound teaching practices. What are absent from the literature on teacher
beliefs on science laboratories are specifically, beginning secondary science teachers’ beliefs
about the purpose of laboratories throughout their planning, implementation, and assessment, and
how those espoused beliefs translate into classroom action as they make initial autonomous
decisions during this first year. In 2002, Tsai called for research that clarifies the relationships
between espoused beliefs and classroom actions. Through an in-depth case study of three first-
year science teachers I examined this gap in the literature, drawing connections between their
espoused beliefs and how they translated those beliefs into classroom actions.

The appeal of laboratories (AAAS, 1990; NRC, 1996; 2000) developed from a desire to
allow students to expand their scientific understandings by doing science (Tobin, 1990). In 1990,
Tobin stated that science education research has failed to provide evidence that students are being given opportunities to meaningfully construct their knowledge. In 1999, Polman supported Tobin’s position by stating that little evidence existed to suggest that these opportunities were going on in the United States or in many other countries.

Science education reforms (AAAS, 1990; NRC, 1996; 2000) and researchers (Bybee, 2000; Hofstein & Lunetta, 2003; Lunetta, 1998) recommend rethinking the role and practice of laboratories in science classrooms. The voice of beginning secondary science teachers as they learn to teach in laboratories is largely absent from the science education literature, but is central to an understanding their processes of learning to teach science, the transition from preservice to inservice teaching, and vital support of induction-year teachers. Examining their beliefs about laboratories as they learn to teach moves our awareness of science classrooms, during the time between teacher education programs and experienced teaching, appreciably toward understanding how and why science laboratory teaching takes place. This understanding will then contribute to a fuller comprehension of why laboratory teaching has failed to result in intended student learning in a majority of science classrooms in the United States (Blosser, 1983; Hofstein & Lunetta, 1982; Tobin, 1990). Not only will an investigation of first-year teachers’ beliefs about laboratories improve our perceptions of science classrooms, but it will also help teacher educators design experiences to assist preservice teachers in aligning their beliefs with reform standards.

By rethinking laboratories through a focus on the beliefs of three beginning science teachers, the mismatch between theory and practice can be examined and a better understanding of how far science education has to go in order to see the potential of laboratory learning met was established in this study. In the following chapter, I describe the case study methodology
that I used to investigate the beliefs of Caroline, Jake, and Lane, three first-year secondary science teachers in Fairfield County. I then describe the science education programs from which they graduated, their school systems, high schools, and my role in the study. Caroline, Jake, and Lane, as well as Fairfield County and all other names used to refer to students and schools except the University of Georgia are pseudonyms. I end chapter three with a description of my data collection and analysis methods.
CHAPTER THREE

METHODS

During the 2003-2004 academic year, I investigated the beliefs of three, first-year, secondary science teachers. Due to the complex nature of beliefs, human actions, and classrooms, I chose to focus on Caroline, Jake, and Lane using case study methodology. I describe my research design below, looking at the particulars of case study and how its methods are suited for this research. Within this section, I describe the standards by which the quality of case studies is determined. Next I examine the methodological perspective that informed my research methods. I then provide the context of the study on which the cases are founded, including descriptions of the participants’ preservice teacher education programs and the schools in which they teach. I explain how Caroline, Jake, and Lane were selected for the study and describe each participant’s experiences from my perspective and in their own words through narratives constructed from interview data. I end this chapter with descriptions of my data collection and analysis methods and my role in the study.

Research Design

I used a multiple-case study approach to make sense of the relationships between my participants’ individual espoused beliefs and classroom actions regarding the use of laboratories to teaching science, and then determine their similarities and differences across cases (Miles & Huberman, 1994). Case study research, like most empirical research, begins with finding something problematic (Merriam, 1988). Be it a person, an organization, or some other area of concern, case study is defined by interest in the individual case (Freakley, 1996; Merriam, 1988;
Stake, 1994; Yin, 1984). Caroline, Jake, and Lane, the participants in this study, each represent a case. Their beliefs as beginning teachers regarding the use of laboratories to teach science is the area of interest due to the often mismatched nature of science education theory and the realities of classrooms, as well as that of the differences between their espoused beliefs and their classroom actions.

According to Stenhouse, “all study is the study of cases” (1979, p. 9) because all phenomena, events, or existences are unique. Each case study investigates the complexities of the real-life of the case. It is this attempt at understanding that is unique (Simons, 1996). The design of case study is conducive to revealing the intricacies of complex social phenomena, like science classrooms, allowing the retention of the holistic and meaningful real-life characteristics under study (Yin, 1984). Case study research recognizes and celebrates “the fact that our knowledge is both personally and socially constructed; our representations inevitably incomplete; that research has the power to stimulate thinking as much as express conclusions; and, crucially, that research…if portrayed in problematical ways can provoke us to think differently” (Stake & Kerr as cited in Simons, 1996, p. 232). It is the search for complexities in ordinary practice within natural habitats that makes case study so valuable for describing issues not easily studied in any other way and quite often taken for granted in their usualness. Teaching is one example of something often taken for granted for its usualness, whereas the mix of knowledge, experiences, personalities, and interactions in classrooms naturally defines them as far more than usual. I sought to investigate the complexities of Caroline, Jake, and Lane’s “natural habitats” during their first year teaching as they used laboratories to teach science because the intricacies of teachers’ beliefs as espoused and enacted are not easily studied outside
of classrooms. The distinctive and messy nature of investigating the beliefs of individual teachers in their classrooms makes case study particularly well-suited for this task.

The cases in this study are intrinsic (Stake, 1994) and interpretive (Merriam, 1988). Three types of case study have been identified by Stake (1994); determined by purpose, these categories are more heuristic than functional because as Stake suggested, such neatly delineated categories are, in practice, rare. Intrinsic case study is described as a study conducted to better understand the case. In contrast, instrumental case study is conducted to refine theory or provide insight into an issue. The third category, collective case study, is defined by its concurrent study of a number of cases “in order to inquire into the phenomenon, population, or general condition” (p. 237). My interest in a better understanding of each participant’s beliefs about laboratories suggested the appropriateness of intrinsic case study. Merriam (1988) identified three additional types of case study based on their final report, descriptive, interpretive, and evaluative; descriptive case studies being those that provide a detailed report of the case, interpretive, being those that use thick description to “develop conceptual categories or to illustrate, support, or challenge theoretical assumptions held prior to the data gathering” (p. 28), and evaluative, being those used to describe, explain, and judge (Merriam, 1988). I sought to focus on each participant individually, describing their beliefs. Through the data analysis, I also examined their beliefs in comparison to each other and to teachers whose beliefs had been studied previously.

No “catalog” of research designs exists to guide case study investigators; however, Yin (1984) identified five especially important components of research design:

(1) a study’s questions;

(2) its propositions, if any;

(3) its unit(s) of analysis;
(4) the logic linking the data to the propositions;

(5) the criteria for interpreting the findings.

Based upon these criteria, case study design is flexible. Choices made by researchers range from what questions they will ask and what issues will aid in investigating their initial concerns, to how to most effectively report the study’s findings so that their questions are answered through the accurate and thorough representation of the case. However, due to the rich, descriptive nature of cases, the researcher’s choices are eventually overshadowed by the reader’s, who incorporates his/her subjectivities and interests into a possibly different interpretation than was originally intended. Stake (1994) warns that an emphasis on researcher-provided comparisons can result in little learning for the reader. Rather, descriptions from the cases should provide the necessary material for a reader intrinsically interested in the case to draw their own comparisons (Stake, 1994). Through thick, rich descriptions of Caroline, Jake, and Lane, I provide my interpretation of their beliefs about laboratories in science teaching. Additionally, I analyze the tensions that emerged as a result of inconsistencies in their beliefs and recommend areas of future research.

An understanding of the critical phenomena of interest depends upon choosing a case well (Patton, 1990; Yin as cited in Stake, 1994). Therefore, once a problem is identified and research questions asked, the next step in case study research is defining the case. Based on the way the researcher’s questions are defined, the case can be an individual, an organization, a place, or any of a number of other things (Yin, 1984). Giving shape to the case requires diligent focus on what it is the researcher is interested in investigating.

In order to understand the case, researchers gather data on the nature of the case, the case’s context including its historical and physical background, information on other cases through which this case is recognized, and people who can inform the case (Stake, 1994). The
historical and physical contexts of Caroline, Jake, and Lane’s cases are presented in this chapter. A multiple-case study approach was employed to examine my participant’s espoused beliefs and classroom actions to determine the applicability of their beliefs across cases (Miles & Huberman, 1994). Stake (1994) suggests that while the case is of interest in and of itself, “we cannot understand the case without knowing about other cases” (p. 237). Other cases used for background and comparisons were described in Chapter Two. Each case is unique and must be understood as such, but that does not preclude the need of a common basis for understanding and talking about cases with similar theoretical or even contextual backgrounds. “People find in case reports certain insights into the human condition, even while they are well aware of the atypicality of the case” (Stake, 1994, p. 241). It is this dichotomy that makes case study research stand out as particularly unique to the researcher and readers. Comparing cases, whether unconsciously or not, is common—a single case study compared with one read about in the literature, multiple cases compared with a case or several cases in the literature, similar cases compared within a multiple case study, or similarities in the case(s) compared with similar previously reported, but alternately investigated phenomena. The tendency to compare cases is common, but should not overshadow the importance of the particularities of each individual case.

Theory plays an important role in case study research, for some, serving to test or refine theory (Merriam, 1988; Yin, 1984), for others, a place in which to fit their data. Case study research can test or build theory; qualitative case study usually builds theory; in education, case studies are almost never used to test theory (Merriam, 1988). I seek to build theory by informing the literature on teacher beliefs, teacher beliefs about laboratories, and research on laboratories.
My goal is to add to the body of research that seeks to understand the complexities of science classrooms.

**Quality in Case Study Research**

Good case study research is difficult to do, because a case study researcher must have a tolerance for ambiguity and must be sensitive, empathic, and a good communicator (Yin, 1984). Stake (1994) encourages qualitative case study researchers to be observational, but more basically reflective, and to spend “substantial time, on site, personally in contact with activities and operations of the case, reflecting, revising meaning of what is going on” (p. 242). I engaged in this type of reflective, in-depth qualitative work by employing ethnographic methods to construct three cases in an effort to develop an understanding of first-year teachers’ beliefs as they planned for, implemented, and assessed laboratories. Megan, the participant in my pilot study, helped me refine and better design and conduct this study. Interactions with Caroline, Jake, and Lane further informed my research as the study progressed.

It was my goal to let each case tell its own story. My subjectivities that lead to choices of data collection, analysis and interpretation, admittedly molded these stories, as will the readers’ subjectivities; however, as much as possible, I share each first-year teacher’s story of her or his beliefs about teaching laboratories. It is admittedly my research questions that revealed their stories, but I hope that the stories that are told are as much as possible, theirs. In order to ensure that this was the case, I engaged in member-checking throughout the research process, encouraging each participant’s feedback as I analyzed and wrote.

I ensured quality in my research by collecting and analyzing data from multiple sources, recording all interviews, transcribing interviews and expanding fieldnotes, encouraging member checking of all data attributed to participants, using verbatim quotes and detailed accounts of
observed events whenever possible, and through peer review of my data analysis throughout the collection and analysis process, as well as throughout the final steps toward a written report. I also identified my subjectivities for the reader in the final report, but more importantly, for me, throughout the data collection and analysis process so that my reader and I were both made constantly aware of my subjectivities and their possible effects on my study.

When collecting data, I followed Wolcott’s (1994) suggestions to talk little and listen a lot, record accurately, begin writing early, write accurately, provide my readers with primary data, return to the site or data often, and seek feedback from my participants and my peers. Remaining diligently cognizant of how my experiences affected my research ensured that my work was trustworthy, quality qualitative research. An exemplary case study must be significant and complete, and must consider alternative perspectives, display sufficient evidence, and be composed in an engaging manner (Yin, 1984). In order to achieve both significance and completeness, and in order to ensure quality in case study research, I represented my participants in ways that ensured the trustworthiness of my research.

**Application to Current Study**

Case study research in education is common and most often qualitative, offering a data collection instrument that is sensitive to context and underlying meaning (Merriam, 1998). Case studies have been effectively employed for studying science teachers in the complex and unique contexts of their classrooms (Briscoe, 1991; Bryan, 2003; Bryan & Abell, 1999; Cronin-Jones, 1991; Duschl & Wright, 1989; Hebert & Worthy, 2001; Hunsaker & Johnson, 1992) and are “ideal design for understanding and interpreting observations of educational phenomena” (Merriam, 1988, p. 2). In educational research, “[t]he ultimate goal of case study research is not necessarily to generate laws that predict outcomes across all classrooms, but rather to build and
verify coherent explanations of how particular types of teachers think or how particular types of classrooms work” (Cronin-Jones, 1991, p. 247). To gain an in-depth understanding of teacher beliefs as they plan for, implement, and assess laboratories during their first-year teaching, I employed ethnographic methods to construct three cases. Each participant constitutes a case. My goal was to portray Caroline, Jake, and Lane’s classrooms and their beliefs regarding teaching science via laboratories, using their words, descriptions, and explanations. By using case study research, I was able to investigate the beliefs of first-year secondary science teachers regarding laboratories through multiple data sources and personal contact with each participant. I wanted to understand the complexity of my participants’ beliefs and the interactions between those beliefs and their classroom actions, to which traditional methods such as surveys and structured interviews do not allow access.

Methodological Perspective

The methodological perspective that guided my research was cognitive constructivism. Cognitive constructivism is useful as a way to frame this study because it helped focus the description and development of each participant’s beliefs, without losing site of the influence of their classroom and school culture. Cobb (1994) supported the use of cognitive constructivist perspectives as the emphasis and the lens of research that focuses on the qualitatively distinct interpretations of the participants and their beliefs, including their pursuit of goals in their classrooms. This focus on the individual’s cognitive constructions of reality was vital to understanding my participants’ beliefs as they pertained to using laboratories to teach science. The social and cultural aspects of each participant’s classroom were included in this study only as they were actively interpreted by them (Cobb, 1994). Before further explaining the usefulness
of cognitive constructivism toward understanding first-year secondary science teachers’ beliefs about laboratories, I first examine constructivism, of which cognitive constructivism is one type.

**Constructivism**

Constructivism is an interpretivist research paradigm whose goal is to understand the world through interpretation of it. The researcher and participant are said to create findings through their interactions with the final aim being a consensus construction (Guba & Lincoln, 1994). Constructivism has many variants, including cognitive, radical, social, and sociohistorical, but for each, constructivism’s foundation remains the same, that “particular actors, in particular places, at particular times, fashion meaning out of events and phenomena through prolonged, complex processes of social interaction involving history, language, and action” (Schwandt, 1994, p. 118). For constructivists, reality is apprehendable as socially and experientially-based mental constructs which are not judged as more or less true, but rather as more or less informed (von Glasersfeld, 1989; Guba & Lincoln, 1994). Knowledge is not a copy of reality (von Glasersfeld, 1996) and is not passive (Schwandt, 1994), it arises from actions, experiences, interpretations, and reflections on experiences or objects in one’s environment. Constructivists therefore, have no access to objective reality since and instead construct and transform it through interactions.

**Cognitive constructivism.** Cognitive constructivist research (Cobb, 1994; von Glasersfeld, 1996; Phillips, 1995) generally focuses on the individual’s knowledge construction and actions insofar as they reflect the individual’s understandings (Bryan, 2003). The participants in this study, while affected by their surroundings and experiences, actively interpreted and negotiated meanings for events based upon their understandings and beliefs. There is no way that I can fully apprehend my participants’ beliefs; however, through this study I developed a consensus
understanding of the participant’s beliefs with each one individually in order to represent their beliefs as closely as possible to their reality through the perspective of cognitive constructivism.

Cognitive constructivists do not deny the importance of the environment, but rather place greater emphasis on the cognizing individual, who responds to events according to the meanings that they have for them (Cobb, 1996). There is an implicit assumption that individuals are participating in cultural practice, but it is ultimately the individual’s constructions and interpretations that are important (Cobb, 1996; von Glasersfeld, 1989) to cognitive constructivists. Learning, therefore, is the result of self-organization, and knowledge is the result of interactions that alter cognitive structures.

I posit that learning is the result of experiences with the social world, and that the social context that any learner participates in directly affects what and how they learn. However, I believe that knowledge for the individual learner is not entirely a social construct. It is the learner’s personal experiences that affect what and how they learn. Therefore, for the purposes of this study, I do not deny the influence of the social context on my participants’ lives—humans are born into a world already constructed by others—however, it is the meaning made by each of my participants regarding their espoused beliefs and classroom actions that drives this study.

Beliefs have a strong cognitive component (Richardson, 1996; Rokeach, as cited in Pajares, 1992). Cognitive constructivism is particularly well-suited for a study of beliefs due to the personal, tacit, and complex nature of the beliefs. Understanding the cognitive complexities of beliefs for each participant is vital to an in-depth appreciation of those beliefs. Cognitive constructivism provides the lens through which I can view my participants’ interviews and classroom interactions. In addition, cognitive constructivism, while not denying the influence of their school culture, focuses on each participant’s personal knowledge constructions. As the basis
for my theoretical framework and understanding of reality, cognitive constructivism is revealed in my dissertation study in the form of my subjectivities, including the research questions that I ask, the interview questions that interest me, my perception of events, what I choose to write down when taking fieldnotes, and how I analyze, interpret, and present my data. Cognitive constructivism influenced how knowledge was constructed in interactions with my participants and my perception of my participants’ construction of knowledge in interactions with colleagues, students, and me. Its use a methodological perspective allowed me to develop a consensus of my participants’ beliefs as they existed at the time that this study was conducted.

Context of Study

To provide context for the study, I discuss below, the preservice teacher education program in which each participant participated and the schools in which they taught during the course of the study. I begin by describing preservice science teacher education at the University of Georgia. I then provide descriptive demographics of the Fairfield County school system, as well as those of Broad River High School, Fairfield County High School, and Stony Creek High School.

*Preservice Science Teacher Education at the University of Georgia*

The University of Georgia’s Secondary Science Education program strives “provide opportunities for experiences that allow teachers to enter education settings with the highest probability of success and effectiveness and, for the longer term, to provide them with the cognitive tools and attitudes needed to continue their professional development” (The University of Georgia, Department of Science Education). Caroline, Jake, and Lane graduated from this teacher education program in the spring of 2003. Each has a degree in science education with a focus in an individual science subject: geology, chemistry, and biology respectively. Caroline
and Lane participated in a traditional methods and curriculum block in the spring and a fall reflections course. Jake participated in a field-based methods block.

The Department of Science Education at The University of Georgia focuses on a variety of aspects of laboratories during their methods blocks, but goals that are most closely related to teaching and learning in the laboratory are the goals of: (a) the implementation of a research-based rationale and (b) the differences in individual’s thinking regarding scientific phenomena (ESCI 4450 & 3450 Syllabi, 2002). In addition to these goals, the syllabi for both blocks emphasized strands that include “science teacher with an understanding of the discipline of science and its nature and…as reflective practitioner in school based experiences”, as well as themes that include “learning, curriculum, planning, conducting instruction, evaluation, and beliefs” (ESCI 4450 & 3450 Syllabi 2002).

Traditionally, methods blocks at the University of Georgia follow a pattern of five weeks of on-campus methods classes, five weeks of school-based placement, and the five weeks on-campus again. Drs. Mary Atwater and Norm Thomson taught these courses (ESCI 4450 & 3450) in the fall of 2002. Dr. Thomson stated in an e-mail correspondence (June 24, 2004, that during this course, Dr. Atwater focuses more heavily on laboratories than he. The laboratory portions of the traditional methods block in which Caroline and Lane participated, emphasized laboratory safety/liability. To fully prepare students for the challenges of teaching, students in this block engaged in a variety of assignments including journaling, lesson planning, and teaching. One assignment, the “Special Laboratory Presentation” (2002 Syllabus) focused on developing and teaching a fifty-five minute laboratory to their classmates. Guidelines included choosing laboratories appropriate for middle or high school students in the field in which each preservice teacher planned to teach. Aside from the aforementioned focus on laboratory safety, no
additional emphasis was placed on laboratories. The reflections course extended this work by teaching them to combine their experiences as science learners, science teachers, observers of science teachers, and readers of expert science knowledge to potentially affect their future teaching. This course took place once-a-week, in the evenings during their student teaching semester.

Jake participated in a “field-based” methods block that met at a local high school, beginning in conjunction with that school’s calendar. During this block, Jake was in regular contact with high school science teachers as he learned to teach. He also interacted daily with his professors, colleagues, and high school students at the field site for the duration of the methods block. Jake and his classmates “alternated their time between their mentor teacher’s classroom where they assisted, tutored, observed, and taught, and university-style classes with professors or high school teachers” (Wallace & Oliver, 2003, p. 161). Their experiences were varied and included discussions of and experiences with laboratory teaching and learning.

Because the curriculum for the “field-based” block was determined primarily through suggestions made by the selected site’s teachers regarding topics they found most important, from semester to semester, the degree to which the block focused on laboratory teaching changed. During Jake’s block, a session on laboratory safety was taught by one of the chemistry teachers at the field site. In addition to this session, one of the professors during the block, Dr. Steve Oliver, used laboratories to emphasize laboratory safety and to encourage the preservice teachers to consider how students come to know something and what it means for students to develop intellectual independence separate from texts and teachers by requiring students to develop a lab that is a “true experiment” (personal communication, June 28, 2004). Dr. Oliver stated that he tends to focus on laboratory safety in the form of “liability, tort, negligence,
contributory negligence, MSDS sheets, proper equipment, proper maintenance, and proper instruction” (e-mail communication, June 28, 2004). Dr. Carolyn Wallace, who taught the instruction section of the block, further described their focus on laboratories when she stated, “we spend about 9-12 (90 minute) class periods on labs in the block” (e-mail communication, June 30, 2004). She stated that the first session on laboratories was “very didactic and positivistic” and focused on laboratory safety. The preservice teachers then moved to 1-2 class period discussions on proper lab set-up, group work, laboratory management, and chemical distribution. They focused next on the nature of science and scientific thinking and reasoning through a laboratory on buoyancy led by Dr. Oliver. Dr. Wallace returned several weeks later to guide a series on inquiry in which the preservice teachers engaged in an inquiry-based laboratory, and then discussed readings about inquiry, before planning their own inquiry-based laboratory (e-mail communication, June 30, 2004). This was followed by an observation of Dr. Wallace as she conducted an inquiry-based laboratory with a ninth-grade class. Following this series of laboratory lessons, the preservice teachers then taught at least one inquiry laboratory and a mini-unit which included laboratories. In addition to these lessons, laboratories may also be emphasized by teachers on-site.

Lane and Jake began teaching during the fall that this study took place. Caroline began teaching the previous spring. In the section that follows, I provide demographics for the schools in which they were employed during their first year teaching.

Fairfield County Schools

Fairfield County is among the fastest growing counties in the United States and is located within a large metropolitan area. The vision of Fairfield County’s schools is focused on achieving “a system of world-class schools where students acquire the knowledge and skills to
be successful as they continue their education at the post secondary level and/or enter the workforce” (http://www.doe.k12.ga.us) Fairfield County reports a student population with 7.4 percent gifted students, 43.2 percent on free and reduced lunch, and a 6.4 percent drop out rate. The participants in this study taught at three of Fairfield County’s high schools, Broad River, Fairfield County, and Stony Creek.

**Broad River High School.** Broad River High School educates approximately 2,400 students annually with 2.4 percent ESOL students and 4.8 percent on free and reduced lunch (as reported in Broad River High School’s 2002-03 Accountability Report). The 2001-2002 student diversity at Broad River was reported as 77.9% White, 7.5% African American, 0.2% American Indian, 7.5% Asian, 5.7% Hispanic, and 1.1% Multiracial. In 2002, 423 students graduated from Broad River. Average daily attendance is reported at 95 percent. The average SAT scores for Broad River during the 2001-02 school year were reported as 503 – verbal, 526 – math, with 88 percent of students tested. This compares to Fairfield County as a whole with scores of 506 – verbal, 527 – math, with 84 percent of students tested. Broad River’s 2001-02 scores on the statewide graduation test were as follows: 95 – writing, 99 – language arts, 98 – mathematics, 91 – social studies, and 83 – math (reported as percentages of students who passed). The county scores were 91, 98, 98, 92, and 83 respectively. Broad River’s Odyssey of the Mind (OM) team competed in the World Competition after placing as finalists in the state and national competitions.

**Fairfield County High School.** Fairfield County High School educates approximately 2,200 students annually with 16.8 percent ESOL students and 43.7 percent on free and reduced lunch. It is the most ethnically diverse in Fairfield County. “Students from more than 70 countries, speaking 23 languages, attend [Fairfield County High School]” (from Fairfield County
High School’s 2002-03 Accountability Report). The 2001-2002 student diversity at Fairfield was reported as 17.0% White, 31.9% African American, 0.1% American Indian, 22.3% Asian, 27.3% Hispanic, and 1.6% Multiracial. In 2002, 333 students graduated from Fairfield. Average daily attendance is reported at 92.9 percent. The average SAT scores for Fairfield during the 2001-02 school year were reported as 442 – verbal, 491 – math, with 69 percent of students tested. Fairfield’s 2001-02 scores on the statewide graduation test were as follows: 70 – writing, 97 – language arts, 97 – mathematics, 91 – social studies, and 74 – math (reported as percentages of students who passed). Fairfield County High School’s students placed 1st in the region in the Science Olympiad and 4th in state.

**Stony Creek High School.** Stony Creek High School educates approximately 1,500 students annually with 1.8 percent ESOL students and 7 percent on free and reduced lunch (as reported in Stony Creek High School’s 2002-03 Accountability Report). The 2001-2002 student diversity at Stony Creek was reported as 84.5.9% White, 7.5% African American, 0.0% American Indian (not reported), 2.9% Asian, 3.8% Hispanic, and 1.4% Multiracial. In 2002, 177 students graduated from Stony Creek. Average daily attendance is reported at 95.5 percent. The average SAT scores for Stony Creek during the 2001-02 school year were reported as 477 – verbal, 498 – math, with 67 percent of students tested. Stony Creek’s 2001-02 scores on the statewide graduation test were as follows: 96 – writing, 99 – language arts, 99 – mathematics, 92 – social studies, and 85 – math (reported as percentages of students who passed).

**Selection of Participants**

Caroline, Jake, and Lane volunteered to participate in this study. Each was a recent graduate of The University of Georgia’s secondary science education program, and was in his/her first year teaching. I made initial contact with each participant through their methods
course and recruited participants who self-identified as willing to use laboratories to teach science in their classrooms, who came from a teacher education program that promotes student-centered science teaching, and who had experiences teaching science laboratories in secondary school settings. Neither participants’ gender nor age was a factor in selection. I presumed that each participant would be at different stages in his/her science content and pedagogical content knowledge development and that these differences would emerge during the study. I also presumed that each participant would be at different stages in his/her understanding and confidence with student-centered science teaching methods and that these differences would also emerge during the study. I therefore sought participants who were at a variety of developmental stages as new teachers, but who all planned to use laboratories as integral components to science teaching in their classrooms.

**Gaining Entry**

As described above, I gained entry with the participants in this study by contacting them while they took part in their methods blocks. I then e-mailed them to maintain contact and gauge their continued interest in participating as my planning for the study progressed. I had met Caroline and Lane a number of times prior their participation in this study and had observed Lane on one occasion during her student teaching. As preservice science teachers, they were active in the state science teachers’ association (GSTA), giving us opportunities to interact socially and collegially. On one occasion, while Caroline and Lane were still students, we discussed science teaching in-depth over dinner during GSTA’s annual meeting. Jake and I met only once, in his methods course, before beginning the study. As a result, I faced a greater challenge building rapport with Jake than with Caroline and Lane. I found that as the study progressed and we became more familiar with one another, my rapport with Jake was quite
similar to that with Caroline and Lane. This is to say that I was welcomed into their classrooms
and communicated with openly. I was allowed access to their students’ interactions during
laboratories and felt comfortable asking questions about differences in their espoused beliefs and
classroom actions during interviews. By showing respect for their time and situations as busy
first-year teachers I was able to build a relationship with each participant that resulted in cases
that well-represent each participant (e-mail communications Caroline, May 10, 2004; Jake, May
04, 2004; Lane, May 17, 2004).

I gained entry to the school system and the participants’ individual schools by first
completing and being approved through the University of Georgia’s IRB application process. I
then applied to work with a single participant during the fall of 2002 for my pilot study in a high
school in Fairfield County. The following spring, I contacted Fairfield County for permission to
continue my study with three additional participants during the 2003-04 school year. After
receiving permission from the county, I contacted the principals of each school via e-mail and
received permission from them as well.

Once I obtained permission to conduct my study, I conducted the first interview with
each participant and provided them with parental and minor consent forms so that I could get
permission to observe and videotape their laboratory teaching. Based upon the return of the
consent forms, the participants’ planning periods and their requests, I negotiated with each
participant the class period that I would observe throughout the semester. I observed Caroline
during 3\textsuperscript{rd} period, Jake during 1\textsuperscript{st}, and Lane during 2\textsuperscript{nd}. Interviews took place during their
planning periods which were 2\textsuperscript{nd}, 2\textsuperscript{nd}, and 3\textsuperscript{rd} periods respectively. During this study, I had few
direct interactions with students in the classrooms in which I worked. Short of answering an
occasional question about why I was videotaping their laboratories, the students appeared to
engage in lessons with few changes in their actions based on my presence. I acknowledge that the addition of a second adult to the classroom likely altered their behavior, but based upon my discussions with each participant this effect was slight.

Description of Participants

To gain a better understanding of each participant and their beliefs during their first year teaching, I provide below, descriptions of each from my perspective and narratives composed of their words taken directly from interview data. Each narrative is used as a means of letting the participant tell his/her own story in his/her own words and is provided to give the reader a sense of the participant from their perspective. Within the narratives, the words in italics are mine and were added for context where necessary. I made minimal chronological changes when constructing the narratives, as a means of providing flow to stories that were sometimes told out of chronological order in response to my interview prompts. I chose to use narratives in this way because at a basic level, humans experience the world as story and make meaning of their experiences by telling their personal stories (Clandinin, 1985; 1992; Clandinin & Connelly, 1986; 1987; 1996; 2000). Caroline, Jake, and Lane’s stories of how they became teachers and how they see themselves as beginning teachers provide a context for their beliefs and actions. Their stories have the potential to reveal the uniqueness and complexity of their classroom experiences and beliefs in a way that is logically understood by each. Narratives are uniquely suited for capturing the complexities inherent in classroom practice (Gudmundsdóttir, 2001), and in this case, provide insight into Caroline, Jake, and Lane’s prior experiences learning and teaching science which can be valuable to understanding their beliefs (Bryan, 2003; Lumpe et al., 2000; Stuart & Thurlow, 2000; Thomas et al., 2001). Additionally, the use of narrative methodologies in educational research allows researchers to gain insights into teachers’
experiences with the realities of daily classroom life and returns some voice of authority to teachers (Carter, 1995; Gudmundsdóttir, 2001).

Caroline East

Caroline East is a vibrant, energetic, engaging physics teacher at Broad River High School. She holds a bachelor’s degree in science education with a concentration in earth science. Caroline’s high school is the same one she attended as a student and the same in which she student taught. In addition to Caroline’s teaching load she was the head cheerleading coach at Broad River High School. Caroline’s beliefs about laboratories were influenced by her experiences as a chemistry student at Broad River High and were significantly shaped by work in her methods courses and student teaching. A primary influence on Caroline’s beliefs about laboratories was her high school chemistry teacher whose fun and engaging classroom developed in her a desire to become a teacher (Interview, 07/21). Caroline’s beliefs about laboratories were additionally influenced by her experience student teaching in a classroom in which she assumed that she would excel in teaching geology; where, in fact, she found teaching physics equally as interesting (Interview, 07/21).

When asked to describe a teaching experience that stood out for her, Caroline focused on an experience from student teaching that deeply affected her future preparation for laboratories. She stated:

I was not prepared for all the questions that I was going to get…I’m just trying to remember what I learned in geology class, just to get through my lesson pretty much, and that was the worst feeling in the world, because they were asking me questions, and I had no idea. That was really embarrassing, and I hated it…That’s why, when I started teaching here, second semester, I was here ‘til probably six or
seven o’clock the first six weeks of school, because I was reading and making
notes and making sure that I covered all of my bases – the fact that I will NEVER
get caught not knowing. It’s not that I don’t know and don’t understand – I’d
never taught it before – I had maybe heard it twice in my whole life, and I just
wasn’t prepared…it’s like I lost all respect right there, and I spent the whole
semester getting it back. Because, I could – I could discipline them and they – you
know, I could make them be quiet – make them listen – but just – you could tell,
the look on their face the first time I didn’t know how to answer their questions,
they – the whole semester they looked at me like, ‘Does she really know what
she’s talking about? She has no idea what she’s doing.’ So I’ll never EVER be
unprepared again! (Interview, 07/21)

Her reaction to the loss of control that she felt caused her to arrive earlier and stay later
than many of her colleagues so that she could be as prepared as possible for future
lessons (Interview, 07/21). This sense of insecurity and frustration deeply influenced
Caroline’s preparation for classes and laboratories and her interactions with her students
throughout her first year teaching by driving her to study the text book in preparation for
questions that might arise. I will further examine Caroline’s beliefs about laboratories in
Chapter Four.

What follows is Caroline’s narrative. Constructed from her own words, her
narrative reveals beliefs about teaching and about laboratories, based on her prior
experiences with science and science teaching. A central component to her narrative is a
tension that arose between Caroline’s desire for her students to have fun and her to her
students’ apathy as she worked toward this goal. I will describe and explore this tension
further in Chapter Four. When asked if her narrative accurately represented her beliefs, she stated that it did (Interview, 03/17).

**Caroline’s Narrative**

I have a bachelor’s of science in education, and my concentration was in earth science. I ended up teaching physics, so that was kind of different. I tried really hard to find a teacher in Fairfield County that did earth science and there was only one, and it was Francis Kelly at Broad River High School. I tried to get her as my mentor for student teaching and I did. And it turns out that she had two geology classes and three physics. So I had to teach physics – student teaching – in order to teach the geology and I really fell in love with it and enjoyed it.

I want to be a teacher because of my high school chemistry teacher, Wesley Michaels. He retired when I was a senior here at Broad River. He taught chemistry, and I had the best time in class – it was the most fun. I’ve loved science forever – I’ve always been interested in science, but just, having so much fun in his class. He made me want to study and want to come to class and want to learn, and I just did well in his class. I knew after that I wanted to be a teacher.

*As a teacher,* I am tough. I start out really hard and I’m fair. I think because I’m young – I think I look young – I am young. I’m twenty-two and it’s almost like they want to challenge my respect. So I come out really strict and really stern. I give a lot of work the whole year, that’s just my personality. I’m very no-nonsense. I’m strict and I’m stern, but I’ll stay after school every day if I have to, to help, and they know that. I’m also kind of anal retentive about planning and being organized. It ruins my whole day if I end first period ten
minutes early. I want to have too much planned, than not enough. I hate it when they just – they have time to do nothing. Because then they talk – and they get loud, and I tell them to be quiet and they look at me like, “But you don’t have anything for us to do.” So my goal is to just be strict and stern and have a lot for them to do to keep them busy. I think that’ll be the best thing for me and for them.

I don’t want to be one of those teachers that just is like whatever, you know, the kids that want to learn will learn; the kids that want to do well will do fine…I feel like if I am going to do that, I might as well just get out of teaching. I want to be the teacher that you know everybody says her class is hard but I learned a lot…I just feel like if you are going to do it, you might as well do it well, but right now, I feel like I am on patrol. I am just not enjoying being here right now. The last couple of weeks I haven’t enjoyed my job. I just feel exhausted every day. I feel like it is a fight to make the kids listen and just to be quiet and behave and it is just like is this really worth it? I have talked with some of the other veteran teachers here, the people that have been teaching for thirty years and I am like is it just me, do I, can you help me, do I need to take a different approach, do I need to do something different, you know, and all the teachers that I have talked to said that it is just so different than it was five years ago, ten years ago, fifteen years ago, and a lot of the teachers that I have talked to have said, you know, if it was like this when I had started I probably wouldn’t have made it thirty years. It is just exhausting, I just, I am miserable.

I like using labs, but I notice more this semester, they don’t seem as effective because I’m not getting the responses that I want. My students tend to
I wish I could figure out a way to make kids not want to be lazy and I don’t know how to do that. I don’t know what an incentive could be, because I could make this class SO fun if they would not be so lazy, but they are and I don’t – lots of times I feel like I waste class time when I could be doing instruction because I try to do fun things and two kids participate. And if I force them to do it, which I’ve done before, then they grunt and they grumble and they drag their feet up here and they do it and then they’re so reluctant to do it they don’t get anything out of it. So I wish I could figure out a way to make them not so lazy. I mean, NOTHING is working with some students. Extra credit doesn’t work! Candy doesn’t work! I mean, some kids, if you say you get candy if you do it, they’re like, “Alright, we’ve got to figure out how to do this.” Any kind of little reward – they get something other than a pat on the back and they’re good to go. But then some are like, “I don’t care. I don’t want to do this.” And I don’t know how to make them interested. Obviously fun labs are not it because they look at
labs as work. They don’t like demonstrations either because all they want to do is go home. They don’t care about their grades because they’re just making enough to pass.

The last two weeks have been miserable, every day it is just like a fight. I keep telling myself to just wait, wait it out and get through Christmas, maybe it is just the end of the semester. We have like twenty days, twenty actual contact class days left. We have like twenty days left before finals start. So I thought I can get through twenty days and maybe in January kind of reevaluate my situation and see if I feel this way still. …do I really want to do this, is this really worth it? Do I really want to have to put up with this every day, just to have two months off in the summer?

*Jake McLean*

Jake McLean is a serious, straight forward, interesting chemistry and physics teacher at Fairfield County High School. He has a bachelor’s degree in science education with a concentration in chemistry. In addition to Jake’s teaching load, he coached baseball for Fairfield County High School. Jake began his master’s degree the summer after his first-year of teaching. Jake is heavily influenced by beliefs developed or confirmed during his high school science classes, methods block, and student teaching. These experiences led him to espouse student-centered but enact teacher-centered beliefs. One of Jake’s primary influences was his high school Advanced Placement chemistry teacher whom he described as challenging, cool, confident, flexible, secure, and smart—who lacked formal classroom structure, used advanced equipment, and made Jake responsible for his own learning (Interview, 07/30). Jake stated that they were like friends and were “on the same level” (Interview, 07/30). He made Jake feel like teaching
would be fun (interview, 07/30). Jake’s sophomore chemistry teacher was very different from his A.P. chemistry teacher, but also influential. Jake described her as a very structured teacher who related to students, knew her science, made Jake responsible for his own learning, and made him feel like he could be a scientist (Interview, 07/30).

During Jake’s methods block, he worked with a fifth-year teacher who he described as “insane”, who “didn’t really lay down the law, so the class was kind of running all over him” (Interview, 07/30). Jake stated that he “was very intimidated by that because there wasn’t much order. It was all the worst kids in a school, all in one class. So I ended up just kind of sitting back and taking notes and what I might do differently” (interview, 07/30).

Following his methods block, Jake began student teaching at the school in which he now works, during which he taught a lesson that proved substantially influential to him due to its chaotic nature (Interview, 07/30). Jake described this experience during an interview:

The plan I’d come up with involved us doing a lot of group work, and I taught the kids how to work out some problems and then they all split up and they taught each other how to do the next step. It sounded really great on paper, and when I did it, it was just mass chaos for me. I was darting to all the different lab tables, checking on each student, trying to help them stay on task and I remember when it was done, I was exhausted. (Interview, 07/30)

This experience left Jake feeling like the freedom that he gave his students and the chaos that resulted meant that he could not teach” (Interview, 07/30). Jake’s focus on order and control is a recurrent theme in Jake’s beliefs that will be investigated further in Chapter Five.

What follows is Jake’s narrative. Constructed from his own words, Jake’s narrative reveals, through his prior experiences as a chemistry student and teaching, his beliefs about
teaching and about laboratories. A central component to Jake’s narrative is the tension that arose between his student-centered espoused beliefs and his teacher-centered need for control.

Jake’s Narrative

In college, I came in as a chemistry major. I hadn’t put much thought into that; I was just really good at chemistry in high school. I realized I didn’t want to be in a lab all day where the best I could ever do was make myself look like a great scientist. I wasn’t after that. So I decided, you know, I like science, I’ll use that to teach. I became a teacher because I wanted something that was people centered where I was giving back – everything else I was interested in would be about me and how I could make myself look really great. I like being around people and I wanted to be able to be a good influence and just kind of know that I left an impact on folks.

When I start teaching, I’m going to just set down the most basic ground rules I can and then I really plan on letting them go at it. I’m picturing a couple of pretty standard rules that are going to happen. There’s going to be order, but I’m hoping it won’t be real boring – overly structured. I hope as the learning process, you know, outside of my classroom rules, I hope there’ll be a lot of freedom – that the students are going to be able to learn the way they learn. And then discussing – getting in the mindset with them that there’s not always one particular right answer. I know science is exact, but a lot of times as we explore, I want to teach them that they don’t have to look for one set answer. I want them to be explorers, I guess, in my class, more than just like sponges that take in what I give them.
One of the first times I got observed as a student teacher, I was really nervous about that. I really had no confidence in my ability because I just felt like I had never done it. I hadn’t subbed. I know I knew my science, but I didn’t feel like I knew how to teach very well. So I spent a long time putting together this real detailed lesson plan, and then I got in there and I went with it. And the plan I’d come up with involved us doing a lot of group work, and I taught the kids how to work out some problems and then they all split up and they taught each other how to do the next step. And it sounded really great on paper, and when I did it, it was just mass chaos for me. I was darting to all the different lab tables, checking on each student, trying to help them stay on task and I remember when it was done, I was exhausted. I just sat in a chair and leaned back and I was just waiting to get ripped into by my supervisor about what she thought about it. And she was going nuts! She thought it was phenomenal. She went on and on – the rest of the year, just thought I was this great teacher and saw this learning, so I don’t know, even now I don’t fully get it, because I still don’t feel like much happened. I still feel like I screwed up and that was insane and I couldn’t do it. Students had a lot of options and they were doing multiple tasks and they had a lot of freedom and they were – apparently they were learning a lot from it and I guess I was so busy managing it that I didn’t see it. So it’s kind of made me not be as quick to be critical of my lessons now. I don’t base the success of my lesson on how I’m feeling at the end of it anymore because I see that they don’t necessarily go together.
Now that I’m teaching, I’m really settling down – I feel like I’m kind of dependent on the other teachers a lot but I’m trying to make myself be okay with that because I know that’s a good thing. But I’m real independent so I’m not use to leaning on them so much, but they’re just being great! They’re always coming by – “Hey, I’m doing this lab…It’s great…prepped enough for you if you want to do it.” So that’s really good! I’m trying not to be day-by-day – trying to be at least week-by-week but that’s not always working out. It’s Wednesday, so by Tuesday afternoon I was caught up – I had all my plans for the rest of the week and that felt good because a lot of times I end up at night – you know, it’s ten o’clock, I’m getting ready to go to bed and I’m like, “Oh! What am I teaching? – I just finished grading all the old papers – what am I doing tomorrow?”

Next year, I’m hoping to be a little more on my own. I think I’ll end up doing the same things I’ve done before, but I don’t want to run next door to Luke every single week or every couple days and get a worksheet from him. I want to at least have the worksheet already in my notebook so I run my own copies. Then there’s some modifications on labs I’ve done that I’ve tried to jot down notes on and I hope to remember little changes on the labs he’s already doing where I can make it better for my teaching style or for my students. Towards the end of this semester, I want to be able to give them something and say “Find the density.” And that’s no big deal and it takes fifteen minutes so maybe we can still do something else later on in the lab period once we found the density. Or like figuring out the unknown given a lot of data. I plan on doing more and more labs and equipping them with different things than just taking a density – give them a
little tool box – maybe only three or four things that they can do. They can take a mass now – if I tell them to take a mass that’s not a big deal, so that’s good – that’s what I’m hoping I can do and to be able to take the words out of my procedure and just give them three easy, quick steps of what to do.

As a student teacher, I had no confidence in my classroom management. I’ve thought about it before and in fact, nothing ever went bad, it’s just something I had coming in – I didn’t think I’d be able to control the class. So, that was always my big concern and that was my basis on the success of a lab was kind of like I said before, “How do I feel coming out? Did all the kids seem to be on task?” And now I’m starting to see – even if a kid is off task, I might only see Paulo for a minute, and if I happened to notice he’s off task, in my head, Paulo did not do the lab. But really, I might have caught him at a bad minute – he’s kind of taking a break. And I didn’t see the connections as much down the road as I do know, like in my lectures coming back to the labs, I didn’t realize what a good tool that could be – it saves trouble for me – I don’t have to get out a demo. or a little visual aid, I have the lab – that’s in their head or most of the time, they’ll remember what they did, so I kind of use that as a mental visual aid now more than I use to. The lab report use to freak me out a lot – that was a bigger deal to me then than it is now. We still do the lab report but I’m trying to be more flexible, I guess…trying to not have such a concrete way that I need the procedure, I guess…I’m going to have to kind of give them more guidelines so they know what’s going on there, but…It’s all kind of a process I guess of evolving to where I am now.
Lane Cannon

Lane Cannon is an organized, energetic, and conscientious teacher. She taught biology at Stony Creek High School and coached the tennis team. During this study, Lane began pursuing her gifted certification and Master’s degree in science education. Lane identified her high school biology teacher as one of the influences on her current teaching beliefs. She describes his teaching in the following statement:

When I was in high school, I took regular biology in the tenth grade, but I also took A.P. biology my senior year, and that was taught by Mr. William Watson...And he was just a really great teacher because I feel like he gave us so many hands-on opportunities. We did so many labs. And I know there’s a certain number of labs that are required for A.P. classes, I just feel like the labs that we did were really interesting and fun and really applicable to what we were learning.

(Interview, 08/04)

Mr. Watson’s interesting, fun, and applicable laboratories were enjoyable to Lane and this type of teaching was what she sought to achieve in her classroom. Her focus on “hands-on” science learning was evident in her espoused beliefs and classroom actions, and will be discussed further in Chapter Six.

Lane sought to engage in reflection on her beliefs and conscientiously endeavored to improve her teaching by discussing what she had learned. On September 10th, Lane handed me a list of things that she had learned about laboratories to that point in the school year. That list included making sure that her directions were clear, constantly checking on student progress, planning ahead, incorporating laboratories into lessons often, and having students design their own laboratories. While her efforts towards clarity in her directions and her goal of having her
students design laboratories were in contrast, this kind of effort at reflective thinking was ever-present in Lane’s journey during her first year teaching. Lane acted on and constantly returned to this idea of self-as-learner throughout the year. She expressed on a number of occasions, a deep desire to learn from her participation in this study and worked hard to interact with me in ways that she felt guided her toward her goal.

What follows is Lane’s narrative. Constructed from her own words, Lane’s narrative reveals her background as a science student and teacher. Her beliefs about teaching and about laboratories, based on her prior experiences are evident here. While not central to her narrative, a tension between her espoused beliefs and classroom actions emerged during the study and will be discussed in Chapter Six.

Lane’s Narrative

I started my freshman year as a pre-med major and then I decided to transfer. I also decided to change my major to secondary science education because I knew the science education department was well-respected and highly ranked. I student taught here at Stony Creek High School where I now have a job.

My choice to become a teacher is a little complicated. Like I said, I started off as a pre-med major and I just really decided that it wasn’t for me. It wasn’t because I couldn’t do the course work or I couldn’t – I had all A’s you know, my freshman year – I think I could have gone into medicine, but I was tutoring military students during the freshman year and I decided this was what I really wanted to do. I found joy in helping other people learn and explaining concepts to people. When I was in high school I had originally wanted to be a teacher and I had really great teachers in high school and I think that’s why I eventually chose
to change my major. And then it all clicked. You know I just really enjoy teaching. Every experience that I’ve had just really solidified that.

I’ve always loved science. Through high school, I had really good science teachers and really enjoyed the field. So that’s why I went into medicine and then when I decided to teach, I decided to stick with science because I enjoy it so much – just the curiosity and all of the different things to learn. I think a lot of times the classroom is really disconnected with the science world…even things like the scientific method, we teach it as like a step-by-step process, but in the field it’s almost like a wheel – you just kind of hop into it at any time – it’s just a real continuation. I think it’s a disservice to students not to try to connect that real world science to what we’re teaching because I mean otherwise it’s just boring and repetitive. And I don’t know exactly how I’m going to do that my first year teaching, you know, try to incorporate all of that into class, but hopefully as I go along I’ll learn different ways and try to.

I think it’s good to just have an organized classroom, first of all – stations, where they know they’re supposed to go, they know where the microscopes are, things like that. I think organization is the key – monitoring students, walking around asking students what’s going on. I mean, they get off task, they talk about homecoming dresses and things like that, but that’s because they’re teenagers, but as long as I’m walking around making sure progress is being made as they’re talking about those things

During student teaching, there was always someone there watching me and I always knew that in the back of my head. I was a little nervous. I wanted to
make sure that everything was done perfectly – not that I don’t want things to go well now and make sure everything is done correctly and the students are doing their lab and working the whole period, things like that, but I guess I’m just more relaxed with them now. I can joke around with them and I just know them better I think. I just have a good relationship with a lot of them. I can go around and talk to them and they ask me “What’s going on?” and I can help explain it to them. So I’m just not nervous about someone hearing me or me saying something wrong or something like that like I was when I was student teaching.

I think for next year, and again, it’s my first year – I don’t have a lot of time, but now that I’ve gone through all of the labs, I can go back and say what worked? what didn’t work? how can I change this to make it more student-directed, student…for them to have more hands-on, to design their own labs, things like that. Reform efforts want most of the labs to be inquiry-based. I think as a first year teacher, number one you are still making sure that you know all the content while teaching it to your students, and number two designing labs and knowing what students, knowing how to lead the students to think for themselves is a little bit difficult for a first year teacher, like what are their misconceptions. Like today, students don’t know about scientific notation and things like that and they are like “my calculator says e to the tenth, what does that mean?” And I didn’t really think about them not knowing those sorts of things and so its just knowing what tends to trip students up and somehow building in the lab for those things, to guide them, you don’t know how students react, you don’t know what it is that you want to make sure that you have an overall idea about what you are
teaching them and things like that. So I think as a first year teacher, you are still learning, and so trying to use all those things in a classroom is difficult. Not to say that you can’t, because I try to do as much as I can, but I think, you know, it is a little bit difficult for a first year teacher because we are still learning all this stuff about the school and trying to take care of all of that as well.

Data Collection

To gain an in-depth understanding of each participant’s beliefs as they planned for, implemented, and assessed laboratories during their first-year teaching, I investigated and constructed three cases. My goal was to portray Caroline, Jake, and Lane’s classrooms and their beliefs regarding teaching science via laboratories, using their words, descriptions, and explanations. To capture my participants’ beliefs, I investigated their espoused beliefs and their classroom actions. Interviews, videotaping, and participant observations were the primary means of data collection in this study (see Appendix A for chart of data collected). I also collected archival data to ensure credibility of the data collected and the resulting interpretations via data triangulation.

I conducted four semi-structured interviews with each participant during their first year teaching, that included think-aloud and stimulated recall techniques (see Appendix B for interview guide). Because interviews were merely guided by my questions, but were responsive to each participant’s descriptions of events related to laboratories, interview questions became more individualized as each interview progressed. I focused interview three on information gathered in prior interviews in an effort to more fully investigate emergent beliefs. I also repeated questions from interviews one and two during interview three as a means of member checking. In addition to being responsive to each participant’s statements when asking questions
during interviews, I used understandings built in prior interviews and through observations to select questions to ask. Interview four served as an additional opportunity for member-checking. All interviews were audiotaped and later transcribed verbatim.

I conducted nine observations in Caroline’s classroom and ten in Jake and Lane’s classrooms as they implemented laboratories. Each observation was negotiated in advance with the participant. I was invited to observe lessons that they defined as laboratories, at their convenience. I videotaped each laboratory lesson for use during portions of interviews in which I utilized stimulated recall. I conducted one observation of each participant as they planned for laboratories. This observation was negotiated in advance with each participant. Two of the participants, Jake and Lane, planned with other teachers of like-subjects after school. Caroline planned during her planning period and during the observation talked through the decisions she made as she planned while I asked questions to clarify. I took fieldnotes during each site visit and expanded them within the next twenty-four hours. Expanded fieldnotes included the scratch notes and verbatim statements taken in the field, as well as remembered details of interactions from each observation. I negotiated with each participant to determine which laboratories would be observed and which would be videotaped.

Additionally, I asked participants to write monthly journals in which they described a laboratory that stood out for them that occurred that month, in the form of an impressionist tale (Van Maanen, 1988). I negotiated with each participant regarding the laboratory about which they chose to write, leaving the choice of a laboratory that went well, went poorly, or a well-planned lab, up to the participant. This aspect of the data collection did not proceed as expected because I met resistance to the additional work; receiving only a few impressionist tales early in the school year from each participant. Ultimately it was not a feature of the study that was central
to my growing understanding of their beliefs and that could not be investigated through interviews, observations, and archival data collection. I also collected lesson plans from each participant and viewed graded student work during an interview in which I asked each participant to discuss their assessment decisions. Participants were given the opportunity to review and confirm all statements, opinions, or ideas attributed to them.

Data Analysis

Data analysis began in the midst of data collection with the generation of questions to ask of the data as I engaged in analysis, as well as questions for the second, third, and fourth interviews (Glesne, 1999; Miles & Huberman, 1994). Over the course of the study, my questions became more individualized to each participant’s experiences. I audiotaped and transcribed interview data and organized all interview transcripts, fieldnotes, and archival data chronologically before reading them from beginning to end several times. Through constant comparison data analysis (Glaser & Strauss, 1967), I generated initial codes and grouped examples of interactions and conversations that fit each code together with notes identifying the day and time they were originally recorded. I then used those codes as a means of initial analysis by labeling units of data and assigning meaning to them (Miles & Huberman, 1994). Coding throughout the data analysis process allowed me to first decontextualize and then recontextualize the raw data into a narrative and a case (Coffey & Atkinson, 1996) for each participant. I clustered codes based on their similarities and differences, and identified the clusters as “themes” (Miles & Huberman, 1994).

Once I identified themes and placed supporting examples with each, I began a more in-depth analysis and an interpretation of how the themes revealed each participant’s beliefs about laboratories (Coffey & Atkinson, 1996; Miles & Huberman, 1994). I placed identified themes
into groups based on their similarities to develop larger categories that organized their beliefs and allowed me to identify the tensions that arose as a result. I sought negative examples or contradictory data in an additional attempt to ensure accuracy of the data reported. I collected and analyzed archival data by reading and rereading them and included the data they contained in the search for common themes.

During the data analysis process, I also identified interview data for use in each participant’s narratives. This data contained information that was also used to develop themes and categories of each participant’s beliefs, but is presented in narrative form as an additional means of data presentation. I constructed participants’ narratives by beginning with the understanding that developed during interviews, and using only their words from those interviews. Suggestions made by Polkinghorne (1995) and Clandinin and Connelly (2000) regarding narrative analysis guided this process. I began with each participant’s descriptions of themselves as teachers as the basis for their narratives because I believed that getting to know them as teachers was a vital first step in understanding their complex beliefs about teaching laboratories. I also included examples that offered supporting evidence through which their espoused beliefs and classroom actions regarding laboratories could be understood. In order to tell their stories, I compiled all interviews and removed the researcher’s words, leaving only those said by each participant. I then read and reread their coded interviews, looking for individual stories. Having identified their stories and done initial chronological moving, I printed the remaining text and began to read it for its ability to reveal their beliefs about laboratories in narrative form. I made every effort to leave the participants’ words and stories intact, doing very little to change verb tense or even the stops and starts in their speech patterns. I aimed to tell each participant’s story through their constructed narratives and the study’s findings, so that Caroline,
Jake, and Lane’s experiences learning to teach science would reveal the complexities and uniqueness of his/her experiences with laboratories.

Role of Researcher

I sought to make my role in this study one of co-researcher. By building rapport, reflectively responding to participants’ questions and interview statements, and engaging in frequent member-checking, I sought to honor their voices as unique and valuable to a better understanding of first-year secondary science teachers’ beliefs regarding use of laboratories in their classrooms. In these ways, I researched this study with my participants.

The subjectivities that I was aware of during this study resulted from: (a) my experiences as a science learner and teacher, (b) the standard that I set for myself as a teacher and the tendency to expect the same in others, (c) my background and knowledge of biology, as well as (d) my experiences with science education research, preservice teacher education, and student teacher supervision, each of which placed me in a position to see everything colored by a different lens than any other researcher would.

My own experiences as a beginning teacher were different from my participants’ in a number of ways—the most significant is that I had no formal teacher education training prior to beginning my teaching career. However, our struggles with our beliefs as well as our schools acceptable norms were quite similar. I participated in my first science laboratory in the third grade—the dissection of a four-foot shark. As a result of this experience, I decided to become a biologist. I pursued a biology degree in college and eventually chose science teaching as a career. I loved everything about teaching from the first time I tried it. However, teaching science using laboratories was a challenge for which I was not remotely prepared. With absolutely no experience teaching – save my 16 years as a student – getting through each lesson was often
daunting. Laboratory days represented chaos and resulted in a tension that I faced between my desire for control and my students desire to have fun. But that chaos turned out to be a rich learning environment for all of us.

As a first-year teacher, I leaned heavily on verification laboratories and more didactic teaching methods. Interestingly, the subjectivity that was particularly present here was my tendency to judge teachers who use worksheets and lead their students through the laboratory. It was through the influence of my teacher certification program—the same one from which my participants graduated—that I was made more and more aware of how little meaningful learning takes place in such an environment. As I struggled to become more student-centered in my own teaching, I became more judgmental of those who did not, or who had the knowledge needed to engage students in such a way but chose not to. This subjectivity was the most significant struggle that I faced during this study. Having been aware of it, however, I hope, allowed me to investigate these beginning teachers’ beliefs with less bias. Being aware of my tendency toward judgment of the teachers’ actions with which I worked and how they were supposed to be teaching, helped me be mindful of the purpose of my presence in their classrooms.

My background in biology was not a bias that stands out from my work with my participants. I assumed prior to this study that my experiences as a biology teacher would cause me to view Lane and her beliefs more favorably and as more in line with my own. I was also concerned that my somewhat limited grasp of the chemistry and physics subject matter might cause me to have trouble fully understanding the laboratories in Jake and Caroline’s classrooms. As it turns out, this area of concern was negligible.

As I learned more about varieties of laboratories and their usefulness, I was given the opportunity to work as a graduate assistant in two methods blocks at the University of Georgia
and to supervise student teachers. These experiences served as very effective ways of preparing me for classroom observations and of tempering the judgmental subjectivity mentioned earlier. Through my work with preservice teachers, I gained perspective on other teachers’ classrooms that one does not get when teaching full time. Additionally, I gained perspective on the challenges that other beginning teachers face.

My understanding of laboratory teaching and learning is better defined today. Currently, I support both verification and inquiry-based laboratories as ways of teaching science, depending upon the teacher’s goal for the lesson. I believe that inquiry-oriented laboratories hold great promise in science teaching; however, I believe that they should only be used when well-planned, organized, and incorporated into the science curriculum by teachers who are prepared to take on the challenges of teaching this way. In addition, I believe that students must be prepared to learn in this way by first engaging in more structured activities that contain inquiry components, teaching necessary skills for inquiry-based learning, prior to the introduction of greater degrees of inquiry.

I acknowledge therefore, that my subjectivities colored the questions I asked, the observations I made, the analysis of the data, and my interactions with my participants. I struggled not to judge Caroline, Jake, and Lane based upon my own biases and sought instead to let them express their beliefs separate from me, but inevitably faced frequent occasions when I had to remind myself of my role and goals for this study. As much as possible, I kept my focus on Caroline, Jake, and Lane.

In the chapters that follow, I present Caroline, Jake, and Lane’s cases respectively. I begin each chapter with an introduction and then discuss the findings in terms of each
participant’s beliefs about laboratories. Additionally, I investigate the tensions that emerged for each participant and the circumstances that fueled them.
CHAPTER FOUR

CAROLINE

“I love laboratories. I would do them every day if I could.” (Interview, 07/21)

Caroline expressed through words and actions, beliefs about the purpose and the structure of laboratories. In this chapter, I discuss both categories of Caroline’s beliefs as they relate to our interviews, archival data, and her classroom actions. Many of Caroline’s beliefs about laboratories concerned the utility of laboratories for motivation. I examine two tensions that emerged for Caroline within her motivation belief set: (a) her desire for her student to see laboratories as fun and their apathetic attitudes toward school and (b) her desire to give her students more responsibility during laboratories and their “conditioning” toward a lack of responsibility. I conclude this chapter by discussing how Caroline framed these tensions. Through the discussion on Caroline’s frames I also examine the circumstances that fueled each tension as they related to Caroline’s beliefs about laboratories.

Caroline’s Beliefs

Caroline’s beliefs about laboratories concerned their: (a) purpose and (b) structure. Like Jake and Lane, these categories of beliefs were emergent from the data rather than defined by Caroline. Her beliefs about purpose included laboratories as learning tools and motivators. Her beliefs about structure included her definition of laboratories and her use of laboratories as verification tools. I provide a summary of Caroline’s espoused beliefs and classroom actions regarding the use of laboratories to teach science in Table 1.
<table>
<thead>
<tr>
<th>Belief Category</th>
<th>Caroline’s Belief</th>
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<tbody>
<tr>
<td>Purpose of Laboratories</td>
<td>Laboratories are useful as learning tools and motivators.</td>
</tr>
<tr>
<td></td>
<td>(a) As learning tools, laboratories teach content and skills useful in “real-life”.</td>
</tr>
<tr>
<td></td>
<td>(b) Fun, competition, and grades motivate/encourage students to engage in laboratories.</td>
</tr>
<tr>
<td>Structure of Laboratories</td>
<td>Laboratories are defined by their structure.</td>
</tr>
<tr>
<td></td>
<td>Laboratories always follow lecture in an effort to verify material.</td>
</tr>
<tr>
<td></td>
<td>Assessment of laboratories verifies lectured material.</td>
</tr>
</tbody>
</table>
Beliefs About Purpose

According to Hodson (1993a), two of the intended purposes for school laboratories include learning scientific knowledge and enhancing student motivation. Consistent with these purposes, Caroline’s beliefs about the purpose of laboratories included their use as: (a) learning tools and (b) motivators.

Laboratories as learning tools. Traditionally, the utility of laboratories as learning tools has included laboratories as preparation for the real world (Crawford, 2000; Kang & Wallace, in press; Tobin, 1986). In addition, laboratories have commonly followed lectures in order to reinforce content taught (Roth et al., 1997). Accordingly, Caroline’s beliefs about the utility of laboratories as learning tools concerned laboratories as means of teaching science content and skills useful in her students real lives.

The utility of laboratories as preparation for the real world was evident in Caroline’s espoused beliefs and classroom actions. Through laboratories, she sought to build skills in her students that they could use outside of her classroom. The skills that she stressed as most important were that of following directions and analyzing laboratory data in light of its fit with reality. In the following excerpt, Caroline described the importance of following directions, stressing preparation for real life:

I give the bulk of the credit if they have the right idea. And I make notes about what they’ve done wrong, but if it’s clear to me that they just blatantly didn’t follow directions and didn’t do anything I really take off a lot of points, because then it doesn’t matter to me if they know how to do it or not – we’re facing a bigger issue, they can’t follow directions and that’s a bigger life skill than even that they know how to calculate speed. If you can’t follow directions, I don’t see how you can be
functional. How do you have a job? How do you do anything if you can’t follow
directions? (Interview, 09/24)

She mentioned “life skills” again with regards to jobs that her students would have in which they
would be expected to problem-solve and follow directions:

It’s kind of a headache for me, but I know that they’re learning more by making
them figure it out for themselves – forcing them to problem solve and life skills…

“What are you going to do in a job when you’re not sure what to do? When you
don’t know the answer. Are you going to say to your boss? How do you do that?
What’s the answer?” I say “There’s nothing wrong with asking how to do
something”, but just telling me you know, “Will you tell me the answer?” “No.”

You know, I say “You’re going to have to learn problem solving. That’s a life skill.
It’s not just for a stupid class, turning in a paper and make sure you get an A. It’s a
life skill here.” (Interview, 07/21)

Caroline’s belief that laboratories taught her students skills that would be essential to their
survival in the real world motivated her to provide her students with learning opportunities that
included the responsibility of following directions.

Caroline expected her students to read and follow written directions, giving only
brief verbal guidance at the beginning of each laboratory. For instance, the following
excerpt from a laboratory on vectors is indicative of her expectations:

This lab is going to be extremely hard for you if you do not take the time to read
through the directions. So I want a couple of minutes of quiet time real quick. I
want you to read through it. I don’t want you to get to the end and say “My data
doesn’t make sense” because you’ve done the whole thing wrong and you’re not
able to complete the lab. So real quickly, just take a couple of minutes – read
through the instructions and then we’ll start. (Observation, 09/19)

Another instance of Caroline’s desire for students to read and follow directions occurred during a
laboratory on Newton’s 3rd Law, when she responded to a student’s question regarding a
laboratory procedure by stating that they should try to figure out how they’re going to set this up
before trying to figure out what materials they need (Observation, 10/30).

In addition to following directions, examples of Caroline’s emphasis on teaching real-life
skills often centered on mathematical problems due to their centrality inside and outside her
classroom. For instance, Caroline used mathematical equations as points of discussion with her
students to introduce and draw them into lessons. During an observation of a velocity lab, she
began class by reviewing a homework problem that related to that day’s laboratory which she
had written on the board (Mr. Smith and Ms. East were racing to school this morning…if Mr.
Smith drove 7.2 miles in 8 minutes and Ms. East’s average velocity was 58.2 m/hr for her 6.9
miles drive, who won the race?). The following is an excerpt from that review in which she
asked mathematical questions based on a real-life situation and the students rapidly answered
based on their homework problem that was written on the board:

Caroline: Nobody knows off the top of your head? How about 0.133?
Student: Yeah.

Caroline: Sure. That sounds good. You trust me right? 7.2 miles divided by 0.133
hours. Uh, did you get 54?

Students: Yes.

Caroline: Yeah? If you can remember. Alright, so his speed was 54 miles per hour.

So we’ve taken care of Mr. Smith’s speed. Then you had to calculate my time -
velocity was 58.2 miles per hour and my distance was 6.9 miles. Finding my time – what’s the equation for time?

Student: Time equals…

Caroline: How do you rearrange the velocity equation to solve for time? Time is what?

Student: Distance divided by velocity.

Caroline: Distance divided by velocity. So we take 6.9 miles divided by 58.2 miles per hour. Miles cancel out and does anybody remember what they got for my time?

(Observation, 09/05)

These mathematical problems typified Caroline’s use of real-life situations in order to interest her students and teach them useful skills. She used laboratories in these cases to teach her students to gauge how their laboratory work related to real-life examples, thereby encouraging them to judge the realistic fit of their responses.

The realistic fit of laboratory work to real life was also apparent in Caroline’s September Impressionist Tale, in which she stated that the frog race laboratory was “a good way to help correct math problems.” By racing their frogs and calculating speed, Caroline believed that her students were able to develop an understanding of units and distance. She described their struggles with math during an interview when she referred to the frog race:

A lot of time they don’t have a good perception of numbers – if they get the wrong answer, they will just leave it and they won’t really look at it. Like, for example, if they calculated the speed of their frog and they did the calculation incorrectly and it was in meters per second and they came up with 100 meters per second – some of them, in lab they might have caught that mistake by looking and
Caroline provided her students with opportunities to examine mathematical results in light of laboratory investigations. By making these comparisons, she felt that they made connections with their real world understandings that clarified what they learned in class. For Caroline, her students’ understanding of math was vital to their success.

By gauging the accuracy of their answers, Caroline used laboratories to correct students’ misconceptions (Interview, 07/21; 11/13). For instance, when referencing a laboratory on vectors, she stated that laboratories are:

- a different way and an easier way for me to say, ‘No, no, you’re doing this wrong. Let me show you why.’ And they can actually see it. They can say, “Okay, I see that I walk in the same direction and that’s why it’s not two vectors.” But I still think a big part of it is just because they get to get up and do something – they get to have fun. (Interview, 09/24)

Ultimately, Caroline believed that when her students left her class, they should have a “good working knowledge” of the content “that they can apply to everyday activities, everyday life, everyday stuff” (Interview, 09/24). An example of an everyday activity to which Caroline expected them to apply their science knowledge can be seen in the following question from a laboratory on Newton’s 1st Law (see Appendix C): “Why is wearing the seatbelt in your car important? Explain your answer in terms of Newton’s 1st Law” (Observation, 10/15). This type of question required students to make connections to their real-life understandings. Caroline believed that laboratories were useful for preparing her students for their lives outside of Broad
River High School including such skills as responsibility, problem solving, critical thinking, communication, and cooperative group skills (Interview, 07/21; 11/13).

Caroline’s beliefs about laboratories as learning tools were integral to her beliefs about the purposes of laboratories for science teaching; however, more salient were her beliefs about laboratories as motivators for science learning. Caroline believed that unless motivated by fun, competition, or grades, her students would not choose to engage in laboratories, rendering the utility of laboratories for learning real-life skills and science, useless.

*Laboratories as motivators.* Using laboratories as motivators is a common practice that focuses on resultant student attitudes toward science. Hofstein and Lunetta (2003) suggest that as motivation for learning, laboratories have the potential to increase student interest. In addition, studies point to having fun as a primary motivator for laboratories (Brickhouse & Bodner, 1992; Kang & Wallace, in press; Tobin, 1986). Accordingly, Caroline’s beliefs about the utility of laboratories as motivators concerned laboratories as: (a) fun, (b) competition, and (c) assessment opportunities for science lessons, but principally focused on fun.

While Caroline’s beliefs about the purpose of laboratories for learning were important to her, they were more significantly influenced by the utility of laboratories for motivation. Caroline believed that laboratories were most effective as motivators for students to engage in classwork. She also used them as incentives for students to work outside of class. Caroline used laboratories because they “grab their attention and make them want to do stuff and – it’s actually like they take the time to figure out what they’re doing” (Interview, 07/21). She suggested that as a result of her focus on fun, her students were “going to learn better because they’re going to be more open to listening because they know that it’s not going to be the same thing every day” (Interview, 09/24). Indicative of the importance that Caroline placed on the utility of laboratories
for motivation, she stated that “it is very unfortunate, but true that students are reluctant to learn any more than the bare minimum, and every day I feel like my job becomes more to keep them entertained, and keep their attention, rather than to teach them science” (September Impressionist Tale). One way that she attempted to entertain her students was through laboratories like the Egg-bungee lesson in which her students were asked to develop a bungee apparatus that could transport a chicken egg during a drop from some height, without the egg breaking. Caroline called this her “favorite lab” due to its “freedom and creativity” (Interview, 07/21). Additionally, she believed that these elements resulted in her students having a good time (Interview, 07/21).

Caroline believed that learning “doesn’t seem so much like work, when they are having fun” (September Impressionist Tale). This belief about the utility of laboratories for motivation via fun undergirds all of Caroline’s beliefs about laboratories; she discussed this belief during each interview (07/21; 09/24; 11/13; 03/17), and during every observation (09/05; 09/19; 09/24; 10/15; 10/22; 10/30; 11/13; 11/20; 12/04), as well as in archival data collected (September Impressionist Tale; October Impressionist Tale). For instance, when describing a laboratory in which her students raced paper frogs that they had created the day before, Caroline wrote “this lab worked out great as a source of practice for the students on their math and computing skills using speed and velocity, and more importantly, they had fun” (September Impressionist Tale).

Caroline’s aspiration for her students to have fun in laboratory emerged from her experiences as a high school student (Interview, 07/21), her preferred learning style (Interview, 07/21), and her desire to make schoolwork less like work (September Impressionist Tale; Interview, 09/24). For example, when she began a laboratory on vectors she stated, “Your mission, if you choose to accept it – it says that you have to plan out your route, which is what we did yesterday. You have to have it approved by your imperial commander—that would be
me” (Observation, 09/19) in a typical effort to infuse fun aspects and her own personality into laboratories. She saw these additions to laboratories as somewhat “cheesy”, but felt like they motivated some students (Interview, 11/13).

In an effort to increase student engagement and motivation, Caroline often included aspects of laboratories that were competitive (Observation, 09/05; 09/24; 10/30; 11/13; 12/04). She believed that competition motivated students to work on laboratories. For example, she motivated her male students by pointing out that the finalists on the frog races were all female (Observation, 09/05). During this same laboratory, students compared their times and returned to their paper frogs to determine ways that they could make them move faster. After the frog race, Caroline used competition in a different way when she said “alright, the first person who brings me on paper, written out, the winner’s speed in cm/sec and m/hr gets extra credit.” She told me after this laboratory that the student who worked hardest on the extra credit assignment was a student that rarely worked at all. In this case, competition was used as a motivator for participation and grades.

When describing another laboratory, Caroline stated that “all the kids wanted to see and do and they actually were talking about, if they missed it the first time you know, you could see them kind of huddled in groups and they’re like ‘We know how to do it now. We know how to do it’” (Interview, 09/24). This evidence of student engagement in laboratories represented to Caroline that they were learning and having fun. In a rocket laboratory in which students were challenged to build a rocket and ensure that it could make the round trip, every student worked throughout the class period to solve the problem, preferably before their classmates (Observation, 10/30). It is clear from these classroom observations that the use of friendly student competition resulted in greater student engagement in laboratory. The following excerpt
from fieldnotes taken during a laboratory in which students participated in a series of activities as a review of a unit on rotational inertia and center of gravity, exemplifies the competitive culture of Caroline’s classroom and its effect on student engagement:

Caroline introduces a center of gravity activity by asking her students to come to the back of the room and watch as she tries to pick up a chair that is set against the back wall. She explains as she does this, the rules of the contest, setting it up as a competition. Each student tries to pick up the chair as the others watch. To the right of the trial area, several students who failed to pick up the chair have set up another chair and others who have not yet tried it gather around this area to practice before attempting the activity in front of the whole class. These students are primarily male and are clearly determined to lift the chair. (Observation, 12/04)

This example of competition was a common occurrence in Caroline’s laboratories. Spurred by Caroline, students often engaged in laboratory activities to do better than their classmates.

Less integral to Caroline’s beliefs about laboratories as motivators, but no less important to Caroline or her students were grades. Caroline’s beliefs about the utility of laboratories for motivation could also be seen in the students’ desire to get good grades. Sensing this, Caroline used grades to motivate students to engage in laboratories. For example, she stated that “I force them to take the responsibility of doing it and doing it right because ultimately they do care if they get a good grade or not. That’s really all that’s on their mind” (Interview, 07/21). She noticed that grades acted as motivators as early as our first interview (07/21), and in her September Impressionist Tale, she stated that “knowing that they could all replace their lowest quiz scores, they really took some time, and put some thought and effort into it.” Grades as
motivators were therefore significant to Caroline’s beliefs about the purpose of laboratories. The effect that grades as motivators had on actual student motivation will be discussed further in the section on tensions.

Caroline’s focus on fun, competition and grades influenced her interactions with her students and the resultant attitudes of both student and teacher. During her first year teaching, a significant tension emerged between Caroline’s beliefs about laboratories as fun motivators and her students’ apathy toward school work. This tension will be examined following an explanation of Caroline’s beliefs about the structure of laboratories.

*Beliefs About Structure*

Many beginning teachers espouse student-centered beliefs but enact teacher-centered beliefs (Brickhouse & Bodner, 1992; Gardiner & Farrangher, 1997; King et al., 2001; Simmons et al., 1999; Tobin, 1986). Brickhouse (1990) attributed this tendency of classroom actions to contradict espoused beliefs to the fact that beginning teachers are apt to seek support in structure through reliance on procedures. Accordingly, Carline sought support in structure via procedures. Caroline’s beliefs about structure concerned: (a) her definition of laboratories and (b) laboratories as verification tools. As verification tools, her beliefs about the structure of laboratories can be further understood as beliefs about (a) directions and (b) assessment.

*Caroline’s definition of laboratories.* Brickhouse and Bodner (1992) suggest that teachers’ experiences are often most heavily influenced by that which they believe is possible in their classrooms, rather than that which they find most desirable. Caroline expressed a sense of frustration regarding what she felt unprepared to do in her laboratories. This frustration was evident in how Caroline defined and used laboratories.
Caroline defined laboratories in general as something in which “you actually have some data. You have to get up out of your seat. You have to move around. You have to actually do something…you have to observe and you have to write, and you have to record, and you have to analyze” (Interview, 07/21). She repeated this view of laboratories in our final interview (03/17). Caroline contrasted laboratories and activities by stating that “activity is something you can sit at your seat and do. You don’t have to record any data – it’s more just observation” (Interview, 07/21). By making this comparison, Caroline revealed her espoused definition of laboratories as active, student-centered lessons. To further define the differences between laboratories and activities, she shared the following activity:

When we did light and color – I let them make color wheels. To me that’s not a lab. I know technically they say, ‘Well, if you’re cutting paper, you can call that a lab to fill up your required lab time.’ But that, to me, is not a lab, that’s an activity because, how much thinking does it take to cut a piece of paper and color it? That’s not a lab. You didn’t have to record any data. You didn’t have to really think about it – kind of mindless work. They didn’t observe anything – they didn’t really learn anything about colors. (Interview, 07/21)

Therefore, Caroline delineated between laboratories and activities based on how much thinking was required of the students, how much they learned, and whether or not they engaged in science process skills such as observing, measuring, and analyzing data.

Caroline did not delineate between types of laboratories (e.g. mini, paper, full) she chose to only use “full” laboratories which took the entire fifty-five minute class period. This decision developed from her belief that as first year teacher, she was not yet able to adequately judge timing of laboratory length. With regard to delineating between types of laboratories, she stated,
“I don’t actually use those terms. I usually don’t do mini-labs. I don’t feel like I am good enough yet at judging time and so I try to every time do a full lab, where we start at the beginning of class and we end at the end of class” (Interview, 11/13).

**Verification as structure.** In class Caroline primarily utilized laboratories as verification tools in which students engaged focused on a single concept, spending most of the class period investigating facets of that topic previously covered in lecture. She believed that one of the primary purposes of laboratories was to verify lectured materials. This purpose was most clearly revealed in the way that verification drove the structure of her laboratories.

Caroline planned her classes so that laboratories always followed lectures and were always followed by the introduction of the next physics topic that she planned to teach (Interview, 11/13). She chose to set up her schedule in this manner because she believed that student understanding in laboratories was built with notes, and helped by content and organization (Planning Observation, 01/22). When Caroline planned for a physics unit, she did so alone, based on a schedule that was roughly dictated by Fairfield County. She used structured, fill-in-the-blank notes when lecturing to her classes because she believed that “they pay more attention and can go faster” (Planning Observation, 01/22) if they do not have to write down every word. Additionally, she stated that she could not describe and discuss things as fully if she gave notes the traditional way, and that giving notes this way focused her students and helped them do better on tests. Through lecture, Caroline sought to structure her classroom and prepare her students for laboratories.

Caroline described herself as “strict”, “stern”, “organized”, and “anal retentive” and described her class as “boot camp” (Interview, 07/21). These descriptors may have had a negative connotation from the perspective of the student, but resulted in a well-run and organized
classroom. With this in mind, Caroline used an average of two minutes at the beginning of each laboratory to either go over homework or review with the class the central tenet of the unit that they were studying during lecture and preparing to investigate via laboratory. Caroline’s beliefs about the structure of laboratories supported this pattern. Concordant with Caroline’s beliefs about the purpose of laboratories as verification of expository lessons, she began each laboratory with reviewed information from previous lessons pertinent to the laboratory.

Central to Caroline’s beliefs about the structure of laboratories as verification and in concert with her self-described personality traits, were the clear, concise directions that she gave verbally and in writing at the beginning of each laboratory. Caroline gave brief directions prior to beginning each lab, which she spent an average of four minutes going over, before encouraging her students to read and follow the written directions themselves. Her students then spent an average of forty minutes conducting the laboratories. The following excerpt from fieldnotes is exemplary of Caroline’s use of verbal directions preceding laboratories (see Appendix C for copy of laboratory) and includes her use of review as a tool to encourage students’ connection between lecture and laboratory:

Caroline: Okay, we’re going to do an inertia lab today. So you need one piece of paper, one lab, one stopwatch. You need one little jar of playdough per group and then one car. You can pick out whatever car you want. I would start out with three books. What you’re going to have to do, is build yourself a ramp using my books, using your books, whatever you want to use. You’re going to take playdough and you’re going to make yourself a little clay person. It might work better if you kind of unfolded the book just so you don’t have a huge drop-off, otherwise you’re little person’s going to fall off when the car jumps off the end of the book. What you’re
going to do it let the car roll down and it’s going to hit a barrier. [Caroline demonstrates] and when it hits that barrier, what’s going to happen because of inertia?

Students: The clay’s going to fall off.

Caroline: The clay’s going to fall off. Why?

Students: The car was stopped by the barrier, but not the clay person.

Caroline: What does Newton’s first law say?

Students: An object in motion tends to stay in motion.

Caroline: An object in motion tends to stay in motion. (Observation, 10/15)

By giving clear directions and reviewing lectured material on Newton’s 1st Law, Caroline’s actions revealed her focus on structuring laboratories so that they verified prior lessons.

Student questioning of Caroline during laboratories was infrequent, suggesting that her directions were clear and easy to follow (Observation, 09/05; 09/19; 09/24; 10/15; 10/22; 10/30; 11/13; 11/20; 10/04). The following was taken from field notes during a laboratory on Newton’s 2nd Law: “Students appear to understand the procedures because they are proceeding through the laboratory without asking Caroline any questions” (Observation, 10/22). While infrequent, students did ask questions during laboratories. For instance, during the following fieldnote excerpt, which occurred during the rocket laboratory on Newton’s 3rd Law, one student expressed the class’s confusion based upon a laboratory procedure which typical of questions asked by Caroline’s third period students:

Student: Hey Miss East, how are you supposed to make it come back?

Caroline: How do you what?

Student: How do you make it come back?
[The lab states that once they figure out how to make their rocket work, they have to figure out how to send it down to one end of the room and return to the other end.]

Caroline: You’ve got to figure out how to make it come back.

Student: Is it possible?

Caroline: Oh, sure it’s possible!

Student: You’re joking right?

Caroline: No, I’m not joking. (Observation, 10/30)

Student questioning of this type also allowed Caroline to gauge student progress and understanding during laboratories, and supplemented her own assessment questioning which took place frequently and represented another aspect of her beliefs about the structure of laboratories as verification tools.

In addition to the centrality of directions in laboratories, Caroline’s beliefs about the structure of laboratories included using questioning as a means of assessment. She described her thinking regarding questioning during laboratories in the following excerpt:

I always kind of float around – “What are you doing?” I’ll say, “What’s going on?” – “I don’t know.” “What do you mean you don’t know, what do you think?” Sometimes they don’t understand. They think when I’m say “What’s going on?” that I want you know, a textbook two-paragraph definition. You know, well they say, “I don’t know what’s going on.” “Well look at it. What’s going on?” And they look at me and they’re like… “Is the light bulb lit?” “Well, that’s what I asked you. I asked you what’s going on?” “Okay, well the light bulbs lit.” “What happens when I take it away?” “Well, the light goes off.” “Okay, you gotta’ start somewhere.” So I kind of try to help them lead into answering their questions. A
lot of times while I’m floating around the lab groups. A lot of times they think – it really bothers them because you know, if they ask me something I’ll say “I don’t know, what do you think?” and they’re like “Does that mean I’m right or does that mean I’m wrong?” (Interview, 07/21)

As evidenced above, Caroline utilized questions to guide her students’ investigations and to check their progress. She often did not answer questions directly. For example, during the vector laboratory (Observation, 09/19), a student asked if a direction that he indicated was south. Caroline responded, “Take a look at your map. Which way do you go first, Matt? Do you go up towards the stairs or back towards Ms. Hampshire’s room?” In addition to questioning during laboratories, Caroline utilized pop-quizzes and tests as means of assessing laboratories (Interview, 07/21).

When asked how she determines when her students learn, Caroline stated, “I don’t know that I have determined an answer for myself for that. Uhm, I could say test scores, but I don’t test well, so tests are not a determination of if I learn well, so uhm, I don’t know. I really don’t know how to tell you that they learn well or not” (Interview, 07/21). Caroline ideally envisioned oral exams as “the best (or one of the best ways) of being able to tell what a student really knows” (October Impressionist Tale), but also used students writing as a means of assessment. Caroline stated that “I wish that I – and I don’t have the time – I wish that I had the time and the resources to make EVERY student talk to me about every lab” (Interview, 09/24). She considered laboratories effective if she:

was able to just kind of correct their misconceptions, so from my point of view, if I can read what they wrote, then I get the feeling that they either understand the word and how to use them – what they mean or if they don’t, if I can at least
correct them, I think that’s effective. I think that’s an effective way of evaluating what they know – through the writing. But, as far as from their point of view, they talked about it for, you know, the week afterwards, so obviously they – it wasn’t one of those things where they did it and then they forgot about it five minutes later, they REALLY kept on thinking about it and they bragged to other classes that they got to do it, and things like that. (Interview, 07/21)

Additionally, her students’ written responses and continued interest in the laboratory suggested to Caroline that a laboratory was successful.

Laboratories for Caroline were fun and offered students opportunities for friendly competition; however, she faced resistance on both fronts from student apathy and conditioning. I now examine the tensions that emerged in both of these areas as Caroline’s first year of teaching progressed.

_Framing Caroline’s Tensions_

Schön (1987) called the perspective from which one attends to their practice, _frames_. Frames are useful ways of viewing teachers’ beliefs and are influenced by experience (Bryan & Abell, 1999). In Caroline’s case, she used a _student reaction frame_ to understand her beliefs about laboratories. Within this frame, two tensions emerged from her beliefs with regards to: (a) her desire for her student to see laboratories as fun and their apathetic attitudes toward school and (b) her desire to give her students more responsibility during laboratories and their “conditioning” toward a lack of responsibility. Caroline viewed her tensions in terms of how her students reacted to laboratories. Caroline’s prior experiences during student teaching as revealed in her narrative, and during her interactions with students during her first year teaching focused her beliefs around laboratories as motivators. Her experiences learning and teaching science
formed frames through which she gradually viewed laboratories as a personal chore, rather than fun.

*Student apathy.* A significant barrier that Caroline faced during laboratories was student apathy. The following excerpt summarizes Caroline’s beliefs about the utility of laboratories for motivation. By focusing on a favorite laboratory, she described the effective aspects of this laboratory as well as the frustration that was a common theme during her second semester of teaching:

I did a lab where they had to build a bungee cord and a bungee apparatus for their egg and I really liked it because I had a ton of materials and I said, “Build and bungee. Work on the bungee apparatus.” And it was almost like they were – they were not mad, but they were like “What do you me to use?” “Well you choose.” They’re not used to having freedom and choice and not having everything spelled out for them a-b-c. But they did it and they built it and we had the competition to see when you dropped your apparatus off the edge of the desk does the egg crack, or how close can you get to the ground without hitting it, and if you hit the ground and your egg breaks then you lose? And then afterwards I made them write a short story about what was going on from the egg’s perspective using physics terms. So, that was one of my favorite labs because they got to build something they got to do on their own. It was really a free, open, you know, creative thing and then I made them write about it. And they had fun – they got really competitive…They had a good time. That’s my favorite lab, (Interview, 07/21)

This description focused on the success of this laboratory from the perspective of fun and competition, but clearly revealed a tension that built between Caroline’s desire to engage her
students in fun, creative laboratories, and her students’ resistance to thinking the sake of learning.

Caroline believed that by making her laboratories fun, her students learned and listened better (Interview, 09/24); however, she saw entertaining her students, rather than teaching science, as a necessary goal of her laboratories (September Impressionist Tale). On the other hand, according to Caroline, laboratories were the only effective ways of teaching science topics but, she saw student apathy as a barrier towards using more student-centered laboratories. Student resistance to Caroline’s efforts to provide an enjoyable learning environment rapidly affected her attitude toward laboratories. She stated during an interview that she was thinking about not doing any more laboratories since her students were not interested, but then quickly reversed:

I’m not going to stop doing them just because – a lot of times kids think they’re fun – they’re fun just because they get to get out of the room and they got to go walk around the halls – and at least that makes them not have such bad attitudes towards my class because at least in my class, they get to get up and they get to do something, and the make’s them at least not dread coming back to class and I think that helps them not to totally shut off, so if for nothing else, I’ll keep doing laboratories just because it keeps them interested. (Interview, 09/24)

This tension developed between Caroline’s belief that students should enjoy laboratories and the reality of her students’ apathy toward working and thinking.

Caroline’s frustration with student apathy was most strongly observed during interviews two and three (09/24; 11/13). In fact, she reported that, while still extremely busy and stressed,
she felt less frustration with her students at the time of our final interview (03/17). Prior to this improved outlook however, she expressed a sense of helplessness that:

I use to feel like if they do a lab it’s going to help them, they’re going to understand. Some of them do, but some of them don’t. Some of them just look at it like it’s a day that they don’t have to listen and they just get to – you know, they’re going to try to follow the directions and fill in the worksheet and turn it in. So I don’t know what I think about it any more. (Interview, 09/24)

Therefore, while Caroline saw improvement in her attitudes toward teaching at the end of the study, her struggle with this tension made her miserable for most of her first year teaching.

Student apathy, while not readily apparent in her third period physics class, was pervasive in Caroline’s other four classes (Interview, 09/24; 11/13). Sixth period was especially challenging for Caroline. She described their reactions to laboratories during an interview by stating that

I have a lot of kids that don’t want to be there and don’t care and they’d rather me just leave them alone. And they just do it [lab] and sometimes they turn it in and it’s not complete and they – I could return it to them and say you need to finish this and they’ll write a little something down and turn it back in. And I don’t know how to make them – I mean, this class does not interest them. I give candy for prizes – that doesn’t interest them. I give bonus points – that doesn’t interest them. Getting up out of their seats does not interest them. Sitting there doesn’t interest them – they’re just totally disengaged from everything. (Interview, 09/24)

Students’ attitudes during laboratories incensed Caroline to the point that she decided on a number of occasions not to allow them to do laboratories. She stated, “I was so mad at sixth
period. I said, ‘Forget it, sixth period is NEVER doing anything like this again’” (Interview, 09/24).

Even though student apathy and frustration did not appear to be problematic during her third period class, there were occasional glimpses into this tension during classroom observations. One example followed a laboratory in which students raced paper frogs to calculate speed and Caroline offered extra credit for the first student finished with the calculations; however, with ten minutes left in class, only four students continued to work on the problems (Observation, 09/05).

In summary, this combination of student apathy and frustration was a fundamental tension created as the result of inconsistencies between Caroline’s desire for her students to have fun and her students’ apathy toward school, which produced a potentially caustic reality for Caroline. She utilized laboratories as learning tools because she valued science knowledge, and as the “best ways to learn science” she continued to return to them even after this tension arose. Because Caroline’s most salient beliefs were about laboratories as motivators, Caroline potentially viewed student apathy toward laboratory work as a significant barrier to her efforts to motivate them to learn. At times, this effort proved too much for her, but as evidence of the centrality of this belief to her belief system, Caroline returned to it repeatedly, even in the face of what seemed to her, insurmountable resistance.

*Student conditioning.* Another tension that emerged for Caroline concerned inconsistencies between her desire to give students greater responsibility during laboratories and what she saw as their “conditioning” toward a lack of responsibility. Based on Caroline’s espoused student-centered beliefs, she tried, but felt as if she failed to give students more freedom via fewer directions in an effort to make her laboratories more student-centered. Her
sense of failure emanated from the student frustration that she sensed when she provided such opportunities. For example, Caroline stated,

The kids hate it. They revolt against it. They shut down completely… they want something written out, very easy to understand, step one, step two, step three; which I don’t understand because they don’t read it anyway. Like you want directions and then you don’t read them, but when you don’t get directions you get mad. Well it is not all about keeping them happy, but it makes it, to me, ten times harder when they are miserable, and when they hate your class. But I found that the less I tell them the more frustrated they get and the less likely they are to try. (Interview, 11/13).

Caroline believed that her students learned “a lot more” from laboratories in which they were given more freedom (Interview, 11/13); however, the type of student revolt described above created tensions between Caroline’s desire to engage her students and her sense that her students were strongly against anything but straight forward, question and the-“right”-answer-opportunities. She described this tension as beginning as early as student teaching, a time in which she described herself as being in complete support of student-centered laboratories—even going so far as to say that she got on her “soapbox” during her science education classes in praise of their effectiveness (Interview, 11/13). When asked how she could have been better prepared to give her students more freedom of choice in her laboratories, she responded by suggesting that preservice teachers be realistically exposed to the ingrained student-conditioning toward seeking a single “right” answer by following specific steps, in addition to the theory about the effectiveness of this kind of teaching and learning (Interview, 11/13).
Caroline was surprised by her students’ negative reactions to learning. She stated that “it surprises me that they don’t care at all” (Interview, 09/24). Caroline attributed their conditioning to students’ learning-history. According to Caroline, her students have “been so conditioned to filling in a worksheet and filling in the blank—they don’t want to have to think about what the answer is. They are totally opposed to doing anything that doesn’t have a set of directions. And they just totally shut down” (Interview, 09/24). Caroline attributed much of their conditioning to other school subjects, as well as other physics teachers, who “give them worksheets and word searches. So I mean its teacher-specific too. I feel like I’m in the minority by doing [laboratories]” (Interview, 09/24). When asked how she can take students conditioned to give rote answers and teach them to think, Caroline responded, “I don’t know if I can. I don’t know if they’ve never had to do it, that I can do it in a semester or in a year” (Interview, 09/24). This sense of hopelessness fueled Caroline’s frustration when conducting laboratories.

In addition to her students’ negative reactions to learning in laboratories, Caroline described their conditioning in another way. She noticed that her students got “freaked out” and were “insecure” when asked to think and reason in laboratories (Interview, 09/24). According to Caroline, her students often expressed frustration during laboratories. For instance, her students got “really agitated” when they didn’t know if they had recorded the “right” answer (Interview, 07/21). Caroline believed that by making them think in laboratory, her students routinely got “mad and frustrated” (Interview, 07/21). She posited that “if you don’t give them the recipe, every single step so that it’s so easy that it’s mindless, they get mad and they get very defensive” (Interview, 09/24). In the following example Caroline described student confusion that resulted from recording differing results:
They were concerned because – I think a lot of it goes back to they want to make sure they get an ‘A’ – they want to make sure that they get 100s and they were worried because they were getting different numbers… They were afraid they did something wrong. They wanted me to tell them what they did wrong so they could fix it a get a 100. (Interview, 09/24)

Her students’ focus on the “right” answer resulted in mounting frustration on Caroline’s part.

Tensions regarding student conditioning that arose during laboratories were also apparent in how they reacted to grades as motivators. For instance, Caroline stated that “I can say your grade depends on this and if they don’t want to do it, they are not going to do it. So I mean, I can’t, I can try to force them, but half of them will not do it. I try to give them incentives, you know, you can get a 110 on this project and it can go in for your lowest quiz grade and a lot of them didn’t do it at all” (Interview, 11/13). However, during the egg drop laboratory (Observation, 11/13) it appeared that grades worked well for most of the class as evidenced by the following excerpt:

As the students prepare their vehicles that support their eggs, a student asks if their successful protection of the egg during the drop is for extra credit. All students stop working to hear Caroline answer that it is for a lab grade – with the following additional extra credit: if their eggs survive 1 meter = 1 point, 1.5 meters = 2 points, 2 meters = 3 points, 2.5 meters = 4 points, and 3+ meters = 5 points. Another student asks if they can drop their egg from the top of the stands at the football stadium for a test grade. The class agrees that this is a good idea.

Therefore, while not always a successful motivator with all of her students, grades did prove an incentive to many.
Both areas of tension that emerged for Caroline during her first year were fueled by her single-minded focus on providing laboratories that her students perceived as fun and in which they took responsibility. Her student reaction frame developed due to inconsistencies between her desires and how her students reacted during laboratories. Caroline’s own attitudes toward science teaching were affected by her students’ reactions to her efforts. She saw their apathy and frustration as a direct reflection of herself as a teacher and struggled with the meaning that that had for her. Ultimately she placed the responsibility of the success or failure of laboratories on her students.

Caroline failed to see laboratories as a source of knowledge generation for her students, instead, focusing on following directions and her students’ roles as excited participants. Her students’ cognitive roles were not emphasized during laboratories. With more time, I believe that I would have witnessed Caroline’s resolve to analyze her motivation and teaching techniques in an effort to discover why these tensions existed and ultimately eliminate them. Repeated experiences with these tensions may result in a realization that the way that she engages her students in laboratories is not working for her. Caroline was not looking at laboratories in terms of learning purpose. Perhaps reframing her beliefs about laboratories toward more cognitive engagement, activity, and motivation, as well as knowledge generation will occur for Caroline. In this case, she may be able to move toward more pedagogical maturity as she reflects on her own expectations and students’ preparedness to meet those expectations. She can then begin to meet them where they are rather than starting where she wants them to be. Her improved attitude toward her students and teaching during our third interview (03/04) may have been the beginning of such a change. With further study, Caroline’s process of reframing can be analyzed. In the chapter that follows, I examine Jake’s beliefs about laboratories. While not markedly different in
some ways from Caroline, his beliefs focused more heavily on control of procedures and student behavior.
CHAPTER FIVE

JAKE

“I can almost never think of a lab that wasn’t a success in some way.” (Interview, 07/30)

Through words and actions, Jake expressed his beliefs about laboratories as they concerned purpose and structure. In this chapter, I discuss both categories of Jake’s beliefs as they relate to our interviews, archival data, and his classroom actions. Jake’s beliefs focused primarily on the structure of laboratories and emphasized control of procedures and student behavior. After explaining Jake’s beliefs about laboratories, I examine a tension that emerged for Jake as a result of inconsistencies in his espoused beliefs about laboratories as student-centered and his classroom actions about his students’ abilities. This tension arose as the result of interactions with his colleagues, but has roots in Jake’s prior experiences as a science learner and teacher. I conclude this chapter by discussing the circumstances that fueled Jake’s tension as they related to his beliefs about laboratories.

Jake’s Beliefs

Jake’s beliefs concerned: (a) the purpose and (b) the structure of laboratories. His beliefs about purpose included laboratories as learning tools and motivators. His beliefs about structure included his definition of laboratories, his need for control in laboratories, and his use of questioning as assessment. I provide a summary of Jake’s espoused beliefs and classroom actions regarding the use of laboratories to teach science in Table 2.
### Table 2

**Jake’s Beliefs**

<table>
<thead>
<tr>
<th>Belief Category</th>
<th>Jake’s Belief</th>
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<tbody>
<tr>
<td><strong>Purpose of Laboratories</strong></td>
<td>Laboratories are useful as learning tools and motivators.</td>
</tr>
<tr>
<td></td>
<td>(a) As learning tools, laboratories teach skills useful in “real-life” and verify course content.</td>
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<tr>
<td></td>
<td>(b) As motivators, grades encourage students to participate carefully in laboratories.</td>
</tr>
<tr>
<td><strong>Structure of Laboratories</strong></td>
<td>Laboratories are defined by their structure.</td>
</tr>
<tr>
<td></td>
<td>Laboratories include a continuum from demonstrations to lab practicum.</td>
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<tr>
<td></td>
<td>Controlling procedures and student-behavior is vital to a successful laboratory.</td>
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<tr>
<td></td>
<td>Assessment of laboratories verifies lectured material.</td>
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</table>
Beliefs About Purpose

Jake espoused the belief that the laboratory served several purposes for science teaching, including:

- pulling the student in,
- showing science as discovery and as the “front end” of all types of learning,
- teaching students the process of thinking like a scientist, and
- helping reinforce lecture (Interview, 07/30).

Like the purposes for laboratories laid out by Hodson (1993a) and Hofstein and Lunetta (2003), Jake’s espoused beliefs concerned enhancing student motivation, teaching laboratory and problem solving skills, and learning scientific habits of mind. However, he struggled with bringing his espoused beliefs into classroom actions, focusing primarily on laboratories as verification tools. When Jake’s espoused beliefs and classroom actions were analyzed, his beliefs about the purpose of laboratories concerned the utility of laboratories for: (a) learning and (b) motivation.

For Jake, laboratories were useful as learning tools and revealed where laboratories fit into the context of science, which included science as preparation for real life and laboratories as verification for expository lessons. In this sense, laboratories were used to teach his students practical real-life skills and to confirm content that Jake believed would be useful during his class, as well as when his students leave high school. Jake’s beliefs about the utility of laboratories for motivation revealed a need he had to maintain tight control over both laboratory and classroom procedures. His preoccupation with control, including technical and manipulative skills, mirrored research on beginning teachers (e.g. Bryan, 2003; Champagne, 1990) and deeply influenced both primary belief categories regarding the purpose and structure of laboratories.
Laboratories as learning tools. Jake believed that the most important purpose for laboratory teaching was providing science content knowledge that would be useful to his students’ real lives. During an interview, Jake expressed this belief when discussing what he saw as the realities of his classroom and his students’ futures when he stated, “My tech kid who is not going to college, I just feel like he will be okay if he doesn’t know a whole lot about nuclear particles. I want him to understand about radiation and how it works, kind of in real-life ways, so when he hears radiation causes cancer, he’ll have some idea why” (Interview, 11/19). Jake believed that in addition to being useful, real-life material engaged his students in class. He supported this when describing the same lesson on radiation by stating, “I think they felt real involved in it. They saw this related to them…cancer is a big thing in a lot of their parents and grandparents lives, so they were pretty into it ‘cause most people don’t know a whole lot about radiation, we just sort of hear the word. So they were real pumped about it” (Interview, 07/30). By including information that he saw as useful to his students’ real lives, Jake made efforts to engage his students’ interest in science.

In addition to knowledge that he felt his students would need after high school, Jake used real-life scenarios during laboratories to connect learning to students’ experiences. For instance, he referenced cooking in a laboratory that included ratios, telling his students that “we’re trying to find a ratio today. If you were cooking, you might see a ratio like two parts salt for every one part pepper. It’s going to be the same here – for every one part of magnesium sulfate, how many parts water are there?” (Observation, 01/14). This type of example was common in Jake’s classroom as he facilitated students’ sense-making of complex chemistry problems. Another example of his incorporation of real-life scenarios into his science laboratories occurred during a laboratory in which students were asked to calculate the speed at which water cooled
(Observation, 01/30). Jake had filled two beakers (per lab group) with hot water and asked that students place a thermometer in each. They were then asked to cover one with a dry paper towel and the other with a wet paper towel. Then he asked a pair of students which set up was cooling faster. After their response, he asked for their explanation and encouraged their thinking with a real-life example about sweating and cooling for humans, asking “why do you think we sweat?” (Observation, 01/30). He repeated this point to other pairs in an effort to get his students to examine their temperature readings in relation to their experiences. In each of these examples, Jake expressed his belief regarding the importance of the real-life applicability of laboratories. For Jake, the realities of his students’ lives necessitated shaping his teaching to their future needs, and he often returned to this focus of real-life during laboratories. His beliefs about the purpose of laboratories as preparation for real-life were foundational to this effort.

In addition to teaching information useful to his students’ real lives, Jake used laboratories as tools for verifying and reinforcing course material, especially that which he felt would be useful in the future. Jake’s laboratories typically followed lectures that introduced pertinent course material that the students could observe in the laboratory. By lecturing and then allowing students the opportunity to engage in laboratories, Jake provided his students with multiple chances to see and do science. The following statement about “cookbook” laboratories, which he used as his primary means of laboratory lessons (Observation 09/04; 09/15; 10/24; 10/28; 10/30; 12/03; 01/14; 01/30), supported Jake’s beliefs about laboratories as verification tools—as “opportunities for the students to see what they’ve learned in lecture” (Interview, 07/30). Prior to beginning many of his laboratories, Jake referenced lectured material. In this example, he reminded his students of Mendeleev’s work on the periodic table before they began to reconstruct the periodic table based upon characteristics of each element:
Jake: What we’re doing, the Mendeleev lab – anybody remember Mendeleev?

Students: He created ‘em! [pointing to the periodic table on the wall at the front of the classroom]

Jake: He didn’t create them, he organized them. How did he organize them?”

Student: In a wonderful way!

Student: He put them on the outside.

Jake: He put them on the outside.

Jake: Some people call him the father of the…

Students: Elements!

Jake: Periodic…

Students: Table!

Jake: The Periodic Table! Yeah. He was the first guy to even to get a basis for that. He’s who started that idea got about the first half of them going and then we filled in the rest. (Observation, 10/02)

Jake reviewed pertinent course material that appeared in the laboratory and prepared his students for conducting the laboratory to verify work that Mendeleev did on characteristics of elements in the periodic table.

*Grades as motivators.* Unlike Caroline, Jake did not use “fun” and competition as motivators in his classroom. Instead, he used grades to motivate students’ laboratory behavior. Jake encouraged his students’ participation in laboratories by reminding them that they would be tested on the material that they were learning. One example of Jake’s use of grades as motivators occurred during a laboratory involving raw eggs in which he said, “You want to be very careful with your egg. If you break your egg, you will not pass the lab” (10/28). In addition to his use of
grades to motivate students to be careful, Jake used grades to encourage completion of pre-laboratory work. For example, he did not allow students to participate in laboratories and gave a grade of zero if they had not completed copying their laboratory sheets before beginning the laboratory (Observation, 10/28; 10/30).

Open-book quizzes were common for Jake as additional ways of motivating students to participate in the technical aspects of laboratories that they emphasized (Observation, 10/02; Planning Observation, 02/24), including copying laboratory handouts during all observed laboratories (Observation 09/04; 09/15; 10/02; 10/24; 10/28; 10/30; 12/03; 01/14; 01/30), with the exception of the laboratory practicum (Observation, 11/19). For instance, during what he called a “paper” lab on the periodic table, Jake stated “Tomorrow, there’s going to be a lab quiz. It’s going to be over both labs, the one from yesterday about density and the one from today. And its OPEN LAB BOOK, so if you don’t have a lab report, what good will that do?” (Observation 10/02). On another occasion, Jake told his class “We can’t move on ‘til you get your sheet ready. Think forward a little bit – a lot of times you have a lab quiz and a lot of you don’t have a lab report because we’re wasting this time right now. Take advantage of it” (10/24). These examples point to a way of motivating his students to work that Jake believed was effective. In the section on assessment as the structure of laboratories, I describe how this type of motivation affected Jake’s assessment decisions.

Beliefs About Structure

The tendency of beginning teachers to espouse student-centered beliefs but enact teacher-centered beliefs (Brickhouse & Bodner, 1992; Bryan, 2003; Gardiner & Farrangher, 1997; King et al., 2001; Simmons et al., 1999; Tobin, 1986) was readily apparent in Jake’s beliefs about the structure of laboratories. Jake’s teaching was didactic (Observation 09/04; 09/15; 10/02; 10/24;
Seeking control above all else, Jake focused his energies on providing detailed procedures that he believed resulted in less chaos. And since Jake gauged the success of his laboratories by the degree of chaos, a controlled classroom signified successful teaching. Jake’s beliefs about structure concerned: (a) his definition of laboratories, (b) control, and (c) questioning as assessment. In this section I return to Jake’s beliefs about laboratories as motivators due to their incorporation in his beliefs about structure.

Jake’s definition of laboratories. Laboratories have been defined in the science education literature as opportunities for students to investigate scientific phenomena through the asking and answering of questions of interest to them, while generating hypotheses and patterns, collecting evidence, and discussing and communicating their results. They have also been defined as experiences in school settings that encourage the interaction of students with materials, in an effort to observe and understand the natural world (Lunetta, 1998; Lunetta & Tamir, 1979; Schwab, 1962). Resonant with these definitions, Jake espoused beliefs that laboratory science is “a hands-on subject…not something you learn in a library exclusively. You’ve got to get out and do it” (Interview, 07/30). Therefore, he used laboratories to let his students see and do science, stating that “they learn better when they ‘see’ it” (Interview, 07/30). He also referenced laboratories in lecture as revealed in the following statement,

If I can go back and reference it later on in a lecture, even a kid who didn’t get it in a lab might be able to get the idea later on. I think a few more students got that law of conservation once we went back and talked about it and I could reference their balloons because they really remembered the balloon like it was there, they just didn’t pick up on the law at the time maybe. (Interview, 10/02)
In another interview, Jake espoused the belief that this ability to reference laboratories later helped him determine if laboratories were successful. He stated, “I suppose if I’m able to reference that later on in a lecture and it’s a tool which helps them understand a hard concept, or especially like science vocab, if I can relate back to our labs, then I’m going to consider it a success” (Interview, 07/30). Therefore, the effect of students seeing and doing laboratories was invaluable to Jake’s espoused definition of laboratories.

One way that I determined Jake’s definitions of laboratories was by examining the laboratory-types that he invited me to observe. Based on my classroom observations, Jake defined laboratories as:

- full-laboratories (Observation, 09/04; 09/15; 10/24; 10/30; 12/03; 01/14; 01/30),
- mini-laboratories (Observation, 10/28),
- paper-laboratories (Observation, 10/02),
- computer laboratories (Planning Observation, 02/24), and
- and lab practicum (Observation, 11/19).

Calling the difference between laboratory types and activities a “pretty blended area” (Interview, 07/30), he considered mini-laboratories easier and more straight-forward than full laboratories, with fewer steps (Interview, 11/19). Based on his definition, most of Jake’s laboratories were full laboratories. In contrast to this definition, with one exception (Observation, 10/30) the full laboratories that I observed had five or fewer, straight-forward directions for the students to follow to completion, which better fit his definition of mini-laboratories.

Cookbook laboratories to Jake were “lazy tools” (Interview, 07/30) which he did not plan to use. In fact, when asked if cookbook laboratories had any redeeming qualities, Jake responded that their benefits are “few and far between” (Interview, 07/30). He defined “cookbook”
laboratories as those “where I’m just figuring out what other people already know. There is a set procedure so that I’m just copying what some other guy already did to learn things. There’s no chance I’m going to stumble upon something neat and find my own discovery… just verification I guess” (Interview, 07/30). For Jake, cookbook laboratories were “survival tool[s]” for first year teachers that he preferred to avoid if he was “able to get some help from other teachers” (Interview, 07/30). This help was not available, which will be discussed further in the section on framing Jake’s tensions. Therefore, Jake found himself primarily using cookbook laboratories to verify lectured material. In concert with Jake’s definitions of laboratories as evidence in his classroom actions, his desire to control of laboratory procedures and student behavior further revealed his beliefs about their structure.

**Control as structure.** Jake’s espoused beliefs about student-centered learning and classroom actions regarding control were in sharp contrast. During our first interview he espoused beliefs that laboratories should be student-centered and focused on the nature of science and then contradicted himself by saying, “maybe in an ideal world, kids are just able to be let loose, but realistically, I need to guide them step-by-step” (Interview, 07/30). This contradiction showed that even at his most student-centered, Jake struggled with how to be student-centered and in control. He explained his beliefs about the relationship between his sense of control and structure when he stated, “I’m a lot more scared…of losing control in my class so I like a lot of structure” (Interview, 07/30). One significant influence on Jake’s need for control concerned an experience student teaching in which he told a story about a day that went particularly well, regardless of his nervousness at being observed and evaluated. Jake’s feelings of success that day resulted from the students’ responses to the demonstrations of acid-base
reactions that he showed them, their “real easy, tangible feedback”, and “the fact that they were not getting out of their seats” (Interview, 07/30).

Jake’s espoused beliefs appeared to change during subsequent interviews to more teacher-centered beliefs; however, he expressed concern that this was the case. For example, during our second interview he said “I’m definitely walking them through it more than I want to – more step-by-step” (Interview, 10/02). In that same interview, Jake’s struggle with his beliefs was further exposed by the following statement “That’s kind of the way I like to do things, more often than not, let them kind of play around with it – explore it and then go back and talk about it. I don’t always give them a lot of prep., except for procedure.” Jake’s need for control conflicted with his desire to provide his students with more student-centered laboratories. By the third interview a transition had taken place as evidenced by the following statement: “the structure of the class stays better and everyone is on the same page if we do it real black and white, these are the rules right or wrong. Then everyone can do it step-by-step with me and no one is lost and they like that, which makes sense” (11/19). Therefore, clear “step-by-step” directions became more and more central to Jake’s espoused beliefs classroom actions as he engaged in his first year teaching.

The way that Jake structured laboratories supported his beliefs about control. For instance, Jake controlled the procedures of each laboratory in a variety of ways, including having students begin each laboratory by copying the purpose, hypothesis, materials, safety precautions, and procedures (09/04; 09/15; 10/02; 10/24; 10/28; 10/30; 12/03; 01/14; 01/30). Jake then asked for his students’ attention as he verbally reviewed the laboratory’s procedures while showing them each step (Observation, 09/04; 09/15; 10/02; 10/24; 10/28; 10/30; 12/03; 01/14; 01/30). The following fieldnote excerpt was taken from the period of time prior to a laboratory on the
law of conservation of mass (see Appendix D for copy of laboratory) and is exemplary of Jake’s beliefs about control:

Jake: “Hopefully you figured out that this is the labs we’re doing today. You need to get at least the basic outline of what’s going on.” [Jake explains as he moves to the overhead and back down the aisle just behind the overhead.]

Jake: “This lab is a very, very simple one. That means you don’t get much help from me. You’re on your own.”

Jake: “Okay, so, hopefully you’re getting a title, purpose – nice and short, hypothesis. We talked about, briefly the law of conservation of mass. Basically, you’re not going to create or destroy any matter.”

Student: Do we need to copy all of what’s on the overhead?

Jake: Yes. I’ll leave it up once the lab starts.

Student: Can I write it in my own words?

Jake: You can but that [copying it] will be quicker than doing it in your own words, unless you think you can do it shorter in your own words.

Jake: So anyways, make sure you understand what we’re talking about today. You cannot create or destroy matter. We might change its form – it might shift around a little bit, but that’s what the law says. So you’re going to see if that’s law’s true or if those scientists who made it up were just fooling themselves. Maybe they were totally wrong. You’re going to tell me after today. Alright?

Jake: The way we’re going to do that…you can see up here we’ve got some flasks, some balloons, and some antacid tablets. Any of these tablets will do. We’ve got eight of them…eight balloons, eight flasks…The procedure’s very
easy. If you’re having trouble figuring out…here’s your chance to not be
confused all day. Balloon, antacid tablet [demonstrating each step while standing
at the front of the classroom] – put tablet in the balloon…it’s sitting in there. I fill
this up [holds up a small flask] a quarter of the way with water…not a whole lot
of water. [Jake then walks forward into the students’ desk area to explain and
demonstrate placing the balloon over the top of the flask without letting the
antacid fall into the water.]
Jake: Then the next thing it says to do is get its mass. What would you use to get
its mass?
Student: Bunsen burner.
Jake: Not a Bunsen burner – close.
Student: Triple beam balance.
Jake: Triple beam balance! I’ve got seven of them around here [referring to the
lab tables that line both sides of the classroom]. So the tablet will be sitting in the
balloon – inside it…It’s hooked up like this [shows class the setup in his hand].
You’ve got a little bit of water already in the flask. [Jake tells students that they
will then mass the whole setup.] Don’t let the tablet fall in the water. This is an
antacid tablet. What do you think happens when you put it in water?
Student: It fizzes.
Jake: It fizzes. So, something will happen. Once it’s done fizzing, we’re going to
weigh it again. To see if weighs more or weighs less. Does that make sense?
Students: Yeah.
Jake: So, when you’re ready to go – I’m going to leave this up here so if you’re not finished copying, you can go ahead and get started with the lab if you want.

(Observation, 09/04)

In this example, Jake controlled the procedure through a thorough verbal review, as well as physical demonstration of the steps. He also exerted control when the student asked if she could write the procedures in her own words and Jake responded by encouraging her to copy is because it would be “faster.” During the same observation, a student asked if it was okay if she made her own hypothesis and Jake answers “Oh, you’re welcome to make your own if you got one. In general though, our hypothesis is, there is this law of conservation of mass. They say it’s a law. It’s probably true. I imagine most people are going to take their word for it” (Observation, 09/04). This excerpt reveals both Jake’s tendency toward didactic laboratory lessons and procedural control. As was the case in each observed laboratory, Jake led his students through each step several times prior to allowing them to try it.

Jake felt that by controlling his students’ behavior through structured, didactic laboratories, he could prevent the chaos that affected him so heavily. For instance, Jake stated that “the main thing is monitoring for me, because if a kid gets stumped and I am not there to help them, they are just going to shut down, they don’t know what to do so they are just going to stand there and if I can’t get around quick enough to help everybody, then my kids are just frustrated and they don’t know what they are doing” (Interview, 11/19). Jake’s need for control also emerged when asked about his worst day teaching. Jake explained that up until that day, his mentor teacher had been in the room with him, covering half of the class and then he was darting all across this long, skinny room and things are just not going well. Kids are getting pretty off-task. I don’t think I explained everything well in advance, so
I’m having to answer the same questions over and over – a couple things of glassware got broke, no ones really answering the analysis questions – so I can just tell – it doesn’t sound like anyone got anything from it and plus, I ran all back and forth. I’m shouting all over the place. Just physically it was exhausting and then mentally I feel like no one learned anything from it. (Interview, 07/30)

He mentioned this same sense of chaos and exhaustion during our second interview when describing his feelings about any laboratory that incorporated a great deal of activity (10/02). Chaos like this during laboratories represented lessons that were not successful.

An additional component to Jake’s beliefs about control focused on the danger of laboratories. By focusing on controlling procedures and behavior, Jake revealed his distrust of his students. He stated “sometimes I won’t let my kids get out of their desks. Sometimes if it’s a little more dangerous, I’m going to do the lab in front of them at my demo table” (07/30). He used fear to control his students’ behavior and, as influenced by his colleagues (Planning Observation, 02/24) to avoid conducting laboratory investigations that had potential risk.

Jake’s use of fear during laboratories was significantly influenced by his colleagues (Planning Observation, 02/24). During their planning meeting on the Enthalpy Chapter (20), Jake’s colleagues discussed what laboratories they would allow their students to conduct, safety precautions that they would take, and what demonstrations they would do. This conversation focused on limiting the students’ access to laboratory materials because Jake’s colleagues believed that their technical level students (as defined by Fairfield County Schools) could not be trusted with complicated and dangerous procedures (Planning Observation, 02/24)—a belief that shaped Jake’s classroom decisions. One example of how Jake used fear to control his students’ behavior occurred during an observation of a laboratory on the conservation of mass.
(Observation, 09/04), in which students combined water and an Alkaseltzer tablet. Jake stated, “Put your goggles on. We’ve already got supplies out. I don’t want these dangerous chemicals in your eyes.” Another example occurred during a laboratory in which Bunsen burners were used, Jake stated, “I need your attention today. You need to listen! You need to be safe today. Obviously, I’m holding matches. I’ve hooked up our gas lines to the Bunsen burner. This is not a lab to mess around with, okay?” (Observation, 09/15). During this same laboratory, Jake’s students tried to soothe him by telling him not to be nervous, in response to his repeated safety precautions (Observation 09/15). Another example of Jake’s use of fear as control occurred during a laboratory in which they placed an egg in a Ziploc bag filled three-quarters of the way with vinegar, Jake stated, “since we’re using acetic ACID – an ACID, we’re definitely going to wear goggles and aprons” (Observation, 10/28). In each of these examples, Jake’s emphasis on safety focused on fear, and while laboratory safety is an important issue with which science teachers struggle, Jake used the inherent dangers in his laboratories as a means of controlling student behavior.

Assessment as structure. Jake’s beliefs about structure also included the utility of laboratories for assessing his students’ understanding of science content. Assessment proved a challenge for Jake because as he stated, “…a lot of times it’s not until test time rolls around that I see whether or not they got it, and by then, if they failed I have to move on, so it’s gone” (Interview, 07/30). When asked how he assessed laboratories, Jake stated that “I would like to test on it, but to be honest our department head likes us all to give the same test, so I give THE tech chem test on the day the tech chem people test for that period, so it’s sort of out of my hands. I throw them in as bonus questions from time to time” (Interview, 10/02). He went on to focus on the importance of testing laboratory material by saying “I think it would be good to test
on it because otherwise, it kind of seems like a lab is just an additional thing I throw in, because they know I test on what I thinks important so if I don’t test on it, I feel like I’m saying ‘it’s not important’” (Interview, 10/02). With this in mind, an inconsistency emerged in Jake’s beliefs regarding assessment because, while he wanted his student to understand that what they learned in laboratory was important, he frequently chose to assess their work based upon “whether or not they did it at all” (Interview, 07/30). This focus on completion failed to allow Jake to examine students’ understandings in laboratories. He chose to assess laboratories based on student completion because he believed that his students struggled academically. For instance, Jake stated that, “a lot of times their averages are hurting so bad I don’t want to grade it right or wrong. If they do it, I want to give them a lot of credit” (Interview, 07/30). Along this same line, Jake believed that by grading for completion supported his students as evidenced by the following statement “on my grading I guess, I’m going to be very lenient. I want to support them – the ones who gave it a try and went out on a limb” (Interview, 10/02).

In addition to other methods, Jake believed that assessing laboratories should include questioning. He used questioning to guide student work and to gauge understanding during laboratories. Jake used a variety of questioning techniques during and following laboratories to assess his students. During one laboratory, he used frequent questioning to guide students toward the big ideas as evidenced in the following excerpt:

Jake: Now weigh it a second time and see how much it changed. So you’re saying – the tablet did go away, but did your – this is conservation of mass, so did your mass get destroyed?

Student: Yes.
Jake: [pointing to their data] A little bit…a very little bit, 0.55%. What if nothing changed? Is there any way that stuff could’ve gotten out? (Observation, 09/04)

Jake used questioning because he thought it was an important means of guiding their discovery. For instance, he stated,

Because they start to play around with it – and they have a general idea. So if you question them, I can just kind of steer them in the right direction without spoon feeding it to them because again, if I tell them, they might remember it…things that they discover though, I think that will really stick out. Most people are more likely to remember that. So, it will help them discover it and prove it to themselves. (Interview, 10/02)

He also used questions in concert with statements to encourage students to consider observations during laboratory. His questions were attention focusing. For instance, during a laboratory on chemical reactions, he did part of the laboratory as a demonstration with small groups, pointing out to each that the test tube contains sulfur and iron filings. He asked his students to observe what happened when he heated the mixture and then asked if they had any questions. “See this gas being given off? That may be something worth observing. It’s kind of red in the bottom – kind of a reddish liquid. More of the sulfur melted than the iron. The iron is doing something. A gas is being given off” (Observation, 12/03). In this way, he focused their attention on the results that he wanted them to notice.

Inconsistencies in Jake’s beliefs about the purpose and structure of laboratories resulted in an emergent tension for Jake. When his espoused beliefs conflicted with the realities of his classroom and his interactions with colleagues, Jake shifted from didactic laboratories which included elements that encouraged student reasoning during the laboratory and in the analysis of
results (Observation, 09/04; 09/15; 10/02) to laboratories which included straightforward, short steps (Observation, 10/24; 10/28; 10/30; 12/03; 01/14; 01/30) that did not include reasoning or analysis. This change appeared to be a permanent one during his first year teaching, and included a move from assessments in the form of summary paragraphs in which students critically analyzed their results to questions that required little or no reasoning and that did not necessitate the use of laboratory manipulations to answer. I discuss these inconsistencies in Jake’s beliefs in the next section.

Framing Jake’s Tension

Underlying Jake’s beliefs about the structure of laboratories are his beliefs about his students’ abilities. This student ability frame appeared to have been fueled by Jake’s prior experiences as a science learner and teacher, as well as through interactions with his colleagues as they planned lessons. Jake had concerns about his technical level students’ interactions with each other and with equipment in laboratories. Control of their behavior and laboratory procedures were two ways that he addressed this concern. Prior to beginning his job at Fairfield County High School, Jake espoused primarily student-centered beliefs. However, just weeks into his first year teaching, his beliefs were markedly different. Causality is difficult to pinpoint here, but one influence, his colleagues, became clear when I observed Jake planning (Observation, 02/24).

Jake planned with other technical level chemistry teachers at his school to develop similar schedules for each unit. Jake’s planning revealed an underlying and prevailing influence on his classroom actions—his colleagues’ opinions and actions based on their beliefs about the abilities of technical level students (Planning Observation, 02/24). The culture of this planning observation clarified for me the source of Jake’s tensions between his espoused beliefs that
students take responsibility in laboratories, learning to think for themselves and his classroom actions suggesting that his students were not capable of engaging safely in or critically thinking during laboratories. Jake believed that his technical level students’ reading ability was “a little behind grade level” and resulted in their intimidation by written procedures (Interview, 10/02). He faced this tension daily with his students, stating that Fairfield County High School’s college prep students are “rumored to be like everybody else’s tech level” (Interview, 11/19) and was surprised by how often he had to review fundamental mathematical and laboratory skills (Interview, 10/02). Jake’s colleagues discussed similar struggles that they faced with their technical level students, and modified their laboratories to reflect their beliefs about students’ abilities and behavior (Planning Observation, 02/24).

As part of Jake’s effort to prepare his students to act like scientists, he espoused the belief that laboratories were useful to teach his students to think, but met resistance from his colleagues (Planning Observation, 02/24) as well as his students’ “conditioning” (Interview, 11/19). His didactic classroom actions stood in stark contrast to his student-centered espoused beliefs. For instance, during an interview Jake espoused the student-centered belief that his students:

- should be able to go and figure it out for themselves because otherwise they are dependent on me or they are dependent on their book…so that will be hard for them here, and then we they leave they are always going to be dependent on somebody else. I think it is important to just kind of free up the students, free them to learn, to figure out their own things, to be able to get by on their own… just the whole idea of science is that you are going to discover things. I think it turns students off if all they do is verify what has already been learned. So, it is going to engage the student more, they are going to be more excited, if we are
letting them do inquiry, not to mention we teach them how to think. (Interview, 11/19)

He identified several positive outcomes of student-centered laboratories like engaging students, getting them excited about science, and teaching them how to think, but acknowledged:

I’m definitely walking them through it more than I want to – more step-by-step. They seem really uncomfortable with me giving them a lot of freedom, which – I don’t know, but I assume that’s just because that’s how it’s been in the past. My special ed team teacher was telling me that that’s one of her frustrations – she feels like the students have been walked through it so much that it’s almost like they’re crippled now – they can’t really stand up on their own and do it. So, I’m TRYING to wean them off it and I’m really hoping and looking forward to the rest of the year that it won’t be like that, that step-by-step, they’ll get more independent as well. They seem more DEPENDENT than I thought and my instructions seem to need a little bit of tweaking. It helps them a lot when they see it. You know, as a teacher, I’m always looking to be able to present it in different ways to catch everybody – that’s something that just blew right over my head that I was going to need to physically demonstrate things that I was doing. I guess I felt like I was giving away the lab if I showed them – if I do the lab myself, which takes me five minutes – it takes them fifty, but really I’m not – because they just seem to forget things so fast. (Interview, 10/02)

Jake struggled with knowledge of the “right” way to conduct a laboratory and the way laboratories worked for him.
In addition to Jake’s experiences with his colleagues during planning meetings, his students’ reactions to laboratories confirmed his beliefs about their abilities. Jake defined his laboratories as successful if students understood “really clearly what [he] expect[ed] of them” (Interview, 10/02); however, he faced constant struggles with his students’ lack of confidence. For example, Jake stated during an interview (11/19) when asked why his students asked many questions during laboratory, “some of it has to be confidence I would think. They are so scared to venture a guess. If it is black and white, right or wrong, they can look it up in the book and fix it. But if it is something where they are writing their reasoning behind something, man I don’t know, there is some kind of mental block.” Jake described student reactions to open-ended aspects of laboratory by stating, “I think if it’s too open-ended – at least most classes I’ve been with, the kids are going to be frustrated – they’re not going to be able to do it ‘cause they’ve grown up around just being fed everything and just having to sit there and take it in” (07/30).

This sense of conditioning became more apparent in Jake’s espoused beliefs and classroom actions following the first interview and the beginning of the school year. Jake used the following terms to describe his students reactions to laboratory: confusion (September Impressionist Tale), uncertainty (September Impressionist Tale), distress (September Impressionist Tale), unsure (September Impressionist Tale), frustrated (Interview, 07/30), uncomfortable (Interview, 10/02), terrified (Interview, 10/02; 11/19).

Jake began incorporating his expectation of his students’ lack of confidence into his verbal laboratory directions. For example, during a laboratory in which students were asked to place an egg into a baggie filled ¾ of the way with vinegar and observe the reaction that took place, Jake anticipated their confusion, “this is the one part you’ll need to catch, otherwise you’ll be second guessing yourself” (Observation, 10/28). And during a laboratory on ionic and
covalent compounds, Jake stated “your procedure is twelve steps – it might have confused you – you’ll be reading through that today, but to make life a lot easier, basically everything on this data table up on the board, which is the exact same as the one in the book, which should also be on your lab sheet” (Observation, 10/30). On another occasion, he stated “a lot of you get really confused once we’re in lab. Today doesn’t have to be that hard. We have four simple steps” during a laboratory in which the following steps were written on the board and in their textbooks, and were repeated verbally:

1) Put 5 ml of ethanol in a beaker.

2) Add a small amount of Cobalt (II) Chloride.

3) Dip Q-tip into solution, on notebook paper, write CoCl₂ in large letters on paper.

4) Put paper on hot plate and observe change. (Observation, 10/24)

He reinforced these directions with the following step-by-step verbal review:

Okay, let’s take a break from writing…focus in…let me explain this to you. I want you to know what’s going on…You’re going to work with one partner. What you’re going to do – let’s see the first step [Jake looks to the board and reads]: put five milliliters of ethanol in a beaker. This is the ethanol. It’s a clear, colorless liquid. And I’ve set out four of these…These go up to ten. You’re going to measure out five milliliters of the liquid, so only about half way up, into a beaker. I’ve got enough beakers here for each group. Transfer it in…not going to take up very much room at all. You’ll have almost no liquid in the bottom. This does not involve a lot of chemicals today. Then, the next step [walks to front of room]…I’ve got my ethanol in here…next step, add a SMALL amount of Cobalt
(II) Chloride – that’s this kind of purplish powder up here. [Jake demonstrates] Just a small amount – this is more than what I need. So there’s plenty in here. You don’t need much – in fact, you usually don’t get as good a results if you use too much. If a little is good doesn’t not mean a lot is better. Then you need to stir it up. That’s the one step I kind of left out…you need to stir it up. In fact, you can just stir it up with the Q-tips over here that way you can’t break any stirring rods which will be nice. Alright, you got a beaker with some alcohol and a little bit of the solid…then, step three has already happened – the Q-tip was already dipped in because you were stirring with it, right? So it’s wet – now on a sheet of paper, you’re going to write out the formula – you may have to dip it more than once because it’s bit. It will take up a whole blank sheet of paper [Jake demonstrates]. Then we move on to the next step. So I’ve written it. It’s going to be clear – you probably won’t be able to see it all that well. Then you’re going to place it on a hotplate. There are four hotplates around the class. The hotplates are on low – you do not need to mess with the temperature setting. You’re just going to place it on there for a few seconds and as soon as you notice a change in the color, you need to remove it. So that’s the lab right there. Does anyone have a question about that? (Observation, 10/24)

In another example of Jake’s emphasis on the simplicity of his laboratories, he stated, “And then you’re just adding observations, so that’s it, step-by-step – it should not be too bad” (Observation, 01/14). This same pattern was repeated when Jake described laboratories in interviews and during student interactions as easy (Observation, 09/04), basic (September Impressionist Tale; Observations, 10/24; 10/28; 10/30), and simple (Observation, 09/04; 10/28;
Interview, 10/02). Therefore, Jake’s espoused beliefs and classroom actions regarding the structure of laboratories were deeply influenced by his beliefs about student confidence.

Jake established a pattern of using the whole class period for what he called “simple” laboratories because he hoped “that’ll kind of make them comfortable” (Interview, 10/02). His use of “simple” laboratories and his beliefs about the structure of laboratories tie into his beliefs about the ability of his students to learn from laboratories and engage in them safely. It appeared from his planning observation that his colleagues held the same beliefs (Planning Observation, 02/24).

Jake’s beliefs about his students’ abilities was confirmed for him by what he saw as a lack of confidence exhibited as students checked for reassurance on procedural steps. For instance, during the excerpt above from the Law of Conservation of Mass laboratory, a student asked if they were supposed to weigh their flask with the balloon and Alkaseltzer tablet attached after the class was instructed verbally and physically to do just that (Observation, 09/04). Another student asked “we need to weigh it again, right”, during that same observation. During my second observation, a student asked about what to write in their conclusion and Jake suggested a sentence about each station, encouraging them to read the directions that are written on the board and that they have copied onto their own paper (Observation, 09/15). This pattern is repeated in each subsequent observation—detailed directions and frequent procedural questions. However, procedural questions were not the only ones that students asked; they also frequently checked their answers with Jake.

Jake’s students spent an average of twenty-seven minutes doing each laboratory which followed an average of sixteen minutes per laboratory copying the laboratory sheet and getting verbal directions prior to beginning the laboratory; however, although Jake’s labs were very
organized and his directions very detailed, student questions were frequent. When Jake used a laboratory that did not include detailed directions, he faced resistance from his students and “blame for inadequate instruction” (August Impressionist Tale), which appeared to result in more detailed directions for future laboratories. This self-perpetuating cycle of detailed laboratories, student questions, more detailed laboratories drove Jake’s classroom actions and appeared to influence his espoused beliefs. Jake expressed his frustration with student conditioning when he stated that to his knowledge,

> Teachers have kind of told them, no this is wrong you are not thinking right…they know they are tech level students, they know, they have got to know the expectations are lower for them; so that must be just sinking into them that they are not capable of thinking the way I want them to and they know and then also another thing, if they get lost on something, I know it frustrates them if it is not black and white, there is a good chance it is going to take me ten or fifteen minutes to get over and help them because everyone is going to need more personal attention. (Interview, 11/19)

Interactions with his students and his colleagues resulted in Jake’s belief that his technical level students could not engage in laboratories in the same ways as other students. His perception that his students believed that there were lower expectations for them was additionally influential.

Throughout Jake’s first year teaching, as his espoused beliefs became more student-centered, his classroom actions remained remarkably steady. Didactic and teacher-centered throughout, Jake’s classroom actions were confirmed and supported through interactions with his colleagues and students. Jake’s beliefs were shaped by his interactions with his colleagues and their beliefs about the abilities of the students with which they worked. Second, his need for
control and his perceived lack of confidence on the part of his students resulted in a more structured, less free classroom than he espoused was idea. Whereas Caroline was in an environment in which she constantly faced the results of her student reaction frame, Jake did not confront his student ability frame because his environment reinforced his beliefs.

Jake’s classroom actions were deeply affected by his student ability frame. He focused on the completion of tasks rather than cognitive engagement of his student. Reframing for Jake had not started at the completion of this study. In order to reframe his perspective of his students’ abilities, Jake needs to develop an understanding of how laboratories facilitate students’ generation of knowledge. With more time, he may have turned toward more autonomy in his espoused beliefs and classroom actions. In addition, I believe that with more confidence and experience, Jake may have sought out more student-centered teaching methods. His reflection in our final e-mail correspondence suggested that he struggled with these possibilities:

I don’t have any changes that I feel need to be made. It was interesting to read and “go back in time” to those interviews before the year started. The whole thing has been such a process to me that it is difficult to see how my ideas have changed over time. Looking at it right now, I see how my own personal situation, abilities, and needs entered my classroom practice. As the year went on, it wore me down. I got to where I didn’t have much energy left and I was really just trying to survive day by day. That meant that I was more and more willing to do whatever the group planning sessions suggested and also that during labs I just didn’t have the energy to allow lots of freedom. I just got to where I was telling them how to do that because it was easier for me and helped me keep my sanity. I had never thought about the conflict between the general group planning team’s
philosophies and my own personal ones. I have beliefs but they seem so fragile and moldable right now. I don’t know if that means I don’t really believe what I think very strongly or if it is simply because I’m still a new teacher. (e-mail communication, May 4, 2004)

Jake’s opportunity to examine his practice as a part of this study allowed him to realize that there were inconsistencies in his espoused beliefs and his classroom actions. However, his current focus on completion and students’ abilities in this reinforcing environment suggest that this tension is likely to remain. One explanation for his student-centered espoused beliefs may be his own experiences as a science learner or his participation in the field-based methods block. This explanation leads me to believe that his core beliefs about science teaching and learning were much more traditional which resulted in their emergence as he taught. One other, and I believe more likely explanation, is that based upon his experiences as a science learner as evidenced in his narrative, Jake held student-centered core beliefs, but because he was a new teacher in an environment of strongly traditional colleagues, his classroom actions followed their lead, creating the tension that emerged. He had the desire, but not the knowledge to conduct laboratories in ways opposed to his experiences. I do not believe that Jake struggled with this tension while he was teaching. As evidenced in the e-mail above, it is possible that the demands of being a first-year science teacher overwhelmed him and made conforming to his colleagues beliefs an easy choice. With time, reflection, and most importantly, support, I believe that Jake would have begun incorporating student-centered laboratories. However, his beliefs were so deeply affected by his colleagues that the environment in which he taught would have to change dramatically to make this a reality.
“You learn best when you see it and perform it yourself.” (Interview, 08/04)

Lane’s beliefs about the purpose and structure of laboratories for science teaching were expressed in words and actions. In this chapter, I discuss both categories of Lane’s beliefs as they relate to our interviews, archival data, and her classroom actions. Lane’s most salient belief concerned the utility of laboratories for procedural control. After explaining her beliefs about laboratories, I examine a tension that emerged for Lane as a result of inconsistencies in her beliefs: the conflict between her espoused, student-centered beliefs and the influence of interactions with her colleagues and students. I conclude this chapter by discussing the circumstances that fueled Lane’s tension as they related to her beliefs about laboratories.

Lane’s Beliefs

Lane’s beliefs concerned: (a) the purpose and (b) the structure of laboratories. Her beliefs about purpose included laboratories as learning tools and motivators. Her beliefs about structure concerned her definition of laboratories and laboratories as procedural control. Control as structure for Lane included her use of directions and questioning during laboratories to guide her students’ laboratory engagement. I provide a summary of Lane’s espoused beliefs and classroom actions regarding the use of laboratories to teach science in Table 3.
## Table 3

Lane’s Beliefs

<table>
<thead>
<tr>
<th>Belief Category</th>
<th>Lane’s Belief</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose of Laboratories</strong></td>
<td>Laboratories are useful as learning tools and motivators.</td>
</tr>
<tr>
<td></td>
<td>(a) As learning tools, laboratories teach “real-life” skills and the nature of science. In addition, they are useful ways to verify lectured material.</td>
</tr>
<tr>
<td></td>
<td>(b) As motivators fun laboratories encourage student engagement in science learning.</td>
</tr>
<tr>
<td><strong>Structure of Laboratories</strong></td>
<td>Laboratories are defined by their structure.</td>
</tr>
<tr>
<td></td>
<td>(a) Laboratories can include a continuum of types: from short, didactic laboratories to longer laboratories with inquiry elements.</td>
</tr>
<tr>
<td></td>
<td>Clear directions and questioning as assessment aid in the utility of laboratories for control.</td>
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Beliefs About Purpose

Lane’s beliefs about the purpose of laboratories concerned laboratories as: (a) learning tools and (b) motivators. Her beliefs about the utility of laboratories for learning focused on teaching her understanding of the nature of science and preparation for real life. In this sense, laboratories were used to teach her students scientific and practical real-life skills. In addition, Lane believed that the purpose of laboratories was to verify course material. As motivators, fun laboratories were effective ways of engaging students in science learning.

Laboratories as learning tools. Lane’s beliefs about the purpose of laboratories primarily emphasized beliefs about the utility of laboratories for learning skills, although some attention was paid to the utility of laboratories for motivation. She believed that her students’ laboratory investigations were helpful tools to teach scientific and real-life skills, useful to them in her class and in the real world. Lane described both types of skills that she believed her students learned during laboratories in the following way: “they’re learning cooperative skills as far as working with a team – technical skills: how to work a microscope, how to use the instruments themselves – and then other skills: writing skills as far as expressing themselves and concluding and summarizing the points of the labs” (Interview, 08/04). Laboratories gave her students the opportunity to engage in learning a wide variety of skills.

The science skills that Lane wanted her students to learn came from her own understanding of the nature of science. Lane described the nature of science as “full of investigation – people who are curious about a subject, experimenting and investigating. I think that science is changing and evolving. New research is being done and things are taking place. The nature of science is that it’s hands-on, it’s in the field, it’s not textbook” (Interview, 08/04). When asked about the importance of laboratories to science teaching, Lane referenced these
same characteristics from her students’ point of view, stating that “they’re seeing it in action. I think that’s really the main purpose and I think it just really teaches students the nature of science – investigative, curiosity-type nature of science in that sense. You know, that’s what science is all about” (Interview, 08/04). Lane’s notion of the nature of science guided her view of laboratory teaching and learning as a hands-on, process-driven practice.

Lane emphasized her understanding of the nature of science in interviews and during my observations. For instance, each of the ten laboratories that I observed (Observation, 09/08; 09/10; 09/22; 10/16; 10/20; 11/12; 11/18; 12/10; 01/13; 01/21) started with the students forming individual hypotheses based on prior knowledge or written information given to them for the laboratory. Lane believed that the process of hypothesis formation was the first step in understanding the nature of science and served to engage her students in critical thinking about the laboratories (Interview, 09/22). In this way, Lane encouraged her student to use their knowledge in laboratory investigations.

In addition to her belief that she encouraged critical thinking through the formation of hypotheses, Lane often included in her lessons elements that stretched her students’ thinking and reasoning skills by asking them to use their prior knowledge to develop understandings of new material. For example, at the end of plasmolysis laboratory (Observation, 09/22), Lane asked her students to conduct a “further investigation” if they had time. The plasmolysis laboratory was based upon lectured course material and reinforced lessons on hyper-, hypo-, and isotonic solutions. The “further investigation” utilized understandings built in the laboratory about the reaction of *Elodea* cells to salt solutions of varying concentrations. After observing their cells shrivel or burst, students could conduct the following: “Plasmolysis is a reversible process. Design a procedure to test this statement. Draw any diagrams that you see and explain how what
you find supports or refutes that statement.” By designing a procedure to reverse plasmolysis, Lane believed that her students learned the nature of scientific investigations. This kind of reasoning was typical of Lane’s approach to fostering learning in laboratories. An interesting point to note here is while Lane incorporated aspects such as this into her laboratories, neither completion of nor participation in the “further investigation” was required of her students. In fact, several groups of students engaged in the design and testing in an effort to complete this particular task; however, some groups did not. By placing “further investigations” of this type at the end of laboratories and not requiring students to attempt them, Lane appeared to give little actual value to her espoused belief about laboratories as means of teaching the nature of science.

“Further investigations” were not the only ways that Lane incorporated teaching scientific skills into her laboratories. She often set up laboratories so that her students had opportunities for discussion and reasoning as they worked. For example, her students engaged in reasoning when discussing the degree (5 being most reactive and 1 being least) of reactions that took place when they added manganese dioxide (MnO₂) to their liver samples during a laboratory on enzymes and reaction rates, as evidenced by the following fieldnote excerpt:

When this test tube reaction takes place, one student calls it a “3” and discussion ensues within the group around the effect that the placement of the sample [only halfway down the tube] had on their findings. Another student suggests that the reaction is a “5” and a third agrees. She then asks what number they gave the first two reactions that they observed, and suggests that compared to the reactions that she’s witnessed, the first few may be “4s” rather than the “5s” that they were given, whereas this one is “clearly a 5.” (Observation, 09/10)
By discussing their findings and compounding variables, and by comparing their results, Lane’s students engaged in conversations that she believed built their understandings of the nature of science and science content. Another example of students engaging in discussions occurred during the cell size laboratory when two students considered one’s mathematical calculations of volume in contrast with her partner’s sand and weight measurements. In this example, the two students were grappling with the differences in their results:

Student: Ms. Cannon, Shannon says I’m wrong.

Student: Which is more reliable – the sand or the math?

Lane: Probably the math.

Student: But Shannon says it’s a lot less than 98.

Lane: What should it be? [The students talk about this as the first one goes back to recalculate his sand measurements]. (Observation, 10/16)

Both mathematically calculating the volume of the cubes that they used to represent cells and filling them with sand to calculate their volume by weight, were accepted means of measuring volume for this laboratory. By doing it both ways, this pair of students compared results and started a discussion of accuracy that they may not have had in other cases. In each example above, Lane’s students were asked to go beyond verification to a deeper understanding of science content and skills.

Lane’s classroom actions were consistent with her espoused beliefs about the nature of science in some of the laboratories that she taught (Observation, 09/10; 09/22; 10/16); however, she primarily engaged in teacher-centered actions which I examine later in conjunction with her beliefs about laboratories as verification tools and about control as her beliefs related to giving clear, concise directions which were used in each laboratory observed (Observation, 09/08;
09/10; 09/22; 10/16; 10/20; 11/12; 11/18; 12/09; 01/13; 01/31). This contrast revealed Lane’s attempts at incorporating student-centered aspects in laboratories, while still primarily maintaining procedural control.

In addition to teaching her students the nature of science, the utility of laboratories for teaching real-life skills was integral to Lane’s planning and implementation of laboratories. In this first example she weaves her understanding of the nature of science into this belief by emphasizing the word “done”: “that’s what we’re really trying to get across to students – how the things they’re studying are done in the real world” (Interview, 08/04). Lane planned to incorporate real-life aspects into laboratories including units on ecology (Interview, 08/04) and genetics (Interview, 08/04). In addition, she consistently used real-life examples to tie laboratory science to students’ prior knowledge. For example, when questioning students on the products of the reactions taking place as oxygen was given off during a reaction in the liver enzyme laboratory (Observation, 09/10) Lane stated, “It’s flammable. That’s why people with oxygen tanks carry little signs around that say ‘please do not light your cigarettes.’ Oxygen gas is highly flammable.” The following excerpt from a student’s reflections, in which he responded to a laboratory on food and land use, further revealed the emphasis Lane placed on real life: “If I were a farmer, then I would only plant 2 seeds where I would want the plant to go, as more than that would just mean competition which does not result in fruitful, healthy plants” (12/10). This kind of laboratory analysis commonly incorporated links to real-life situations, like farming, in an effort to help students better understand the concept of competition. In addition to pointing out the real-life applicability of laboratories to her students, Lane thought through connections to real life and their impact on her students, as she reflected on laboratories as evidenced in the following statement about the organic compound laboratory:
We had been talking about all of these organic compounds: carbohydrates, proteins, lipids, and things like that. And I think a lot of times those things are abstract to students. I mean, glucose molecules and chains of glucose put together make starch. I think one of the main purposes was just to allow students to make that connection between foods that we eat – ham and gravy – and what’s contained in those, instead of showing that foods have proteins, foods have carbohydrates – trying to make the abstract more concrete. (Observation, 09/08)

By connecting organic compounds to the foods that her students eat, Lane attempted to attach laboratory learning to students’ prior knowledge. Her students incorporated real-life examples in their own discussions during laboratory as well. For example, during a laboratory on camouflage and adaptation, students discussed the following when the class realized that they had collected greater numbers of yellow “worms” during laboratory:

The class collected more yellow worms than any other color and one student pointed out that scientists have found that when looking at a lot of colors, you are supposed to see yellow first. Lane stated that she heard that you are supposed to paint children’s rooms in yellow to stimulate brain development (Observation, 01/13).

By tying laboratories to their experiences, Lane’s students showed that they made connections as they learned in the laboratory.

Lane used real-life examples to make abstract ideas in laboratories more concrete (Interview, 08/04; 09/22). In addition, she frequently incorporated lecture into her laboratories as a way to reinforce content and teach scientific and useful life skills (Observation, 09/08; 09/10; 10/20; 11/18; 01/13). In this way, Lane used laboratories to verify expository lessons. For
instance, during a laboratory on cell size (Observation, 10/16) which followed a cell size lecture, she reminded her students that “the DNA can only control a certain amount of cytoplasm, right? Once it gets too large, the DNA cannot effectively control everything that happens in the cell. I mentioned that if I were in a gym of 10,000 students, I would not be able to control all of those students. It needs to keep things small.” By making this statement, she referenced something (a gymnasium) with which her students were familiar and tied it to this new, unfamiliar idea of the importance of cells being small in order to maintain control over their functions. In another example, having studied enzyme function in class the previous day, Lane used a laboratory (Observation, 09/10) in which students investigated the effects of hydrogen peroxide on liver that had been treated in a variety of ways (e.g. fresh, boiled, ground, soaked in hydrochloric acid). She then stated in the interview that followed:

I think it worked because they saw all the different pieces of liver and they kind of can make a connection to the function of enzymes as related to different pHs, different temperatures, solid chunks versus ground. And so again, enzymes are one of those things like ‘Huh? What’s an enzyme?’ proteins as well, ‘What’s a protein?’ I think that just kind of again, takes the abstract and makes it a little more concrete for them. (Interview, 09/22)

By making lectured information more concrete, Lane believed that laboratories interested students more and helped them remember lectured lessons (Interview, 09/22). She clarified her beliefs about the utility of laboratories as verification tools when she stated:

I think biology is a lot of memorization – I mean really, there are a lot of concepts that you have to introduce to students in a very short amount of time and I think that labs take those concepts and help put them into concrete things the students
can understand. They should allow students to think critically for the most part about what they should see, what they did see, and relating what happened during the lab to concepts we’re discussing in class. So, kind of a reinforcing tool.

(Interview, 09/22)

For Lane, learning was a matter of remembering and using laboratories as verification tools reinforced this belief. Another example of Lane’s belief about the utility of laboratories as verification tools occurred during the laboratory on cell size and surface area to volume ratios (Observation, 10/16). Following that laboratory, Lane explained in notes that she included in her lesson plan “yesterday, we began talking about why cells divide & how it happens. We talked about the fact that cells need a high surface area to volume ratio in order to transport material into & out of cells efficiently, BUT I feel that students hear those words, but don’t/can’t visualize the connection” (Lesson Plan, 10/16). By doing the laboratory after the lecture, she believed that they were then able to make that connection. And during a laboratory on mitosis, Lane stated “first of all, you have to be able to identify all of these stages.” She then reminded them that they should be able to do that since they saw the cells in various mitotic stages on Friday (Observation, 10/16).

In each of the examples above, Lane supported laboratories as useful ways to verify lectured material; however, in the following excerpt, she confronted a struggle that she had with the fact that she almost always led with lecture when she believed that leading with laboratory would be more beneficial to her students:

I think a lot of times when you lecture first, students are like ‘I have heard it before and I have already learned it’, and I think if you lead with a lab a lot of times, first of all they are not bored by it already. It is a new topic and they are
interested in it and I think that helps with motivation – they get excited about the lab. And then second of all, I think that if you tell them what is going to happen before it happens, what’s the point of doing it. And so, I think that they can go in and they may have misconceptions and they may not know, but they are going to learn from the lab. And again, I think that is where it gets accomplished a lot of times (Interview, 12/10)

Lane recognized the value of using laboratories to lead and to follow lecture. She espoused value for both kinds of laboratories and believed that by using both, she gave her students opportunities to learn biology concepts in a greater variety of ways, thus improving their chances of grasping the material.

In an attempt to incorporate more student-centered laboratory work into her classroom, Lane originally planned the liver laboratory (Observation, 09/10) to be student-designed, but found that they ran out of time to do so during the preceding class period. When asked about the realities of conducting student-designed and directed laboratories, Lane suggested that they require more planning and time that she believed she did not have as a first year teacher (Interview, 12/10). Lane believed that such laboratories increased student interest and learning, and she therefore planned to use them more often as she gained more teaching experience (Interview, 09/22). However, while Lane espoused the belief that leading science learning with a laboratory was valuable, her classroom actions did not support this vision.

Lane believed that laboratories were valuable ways to teach her students science and real-life skills, as well as ways to verify course material. She espoused student-centered beliefs and attempted to enact student-centered aspects of laboratories, but more often than not, her laboratories were entirely teacher-centered. Lane placed greater emphasis on laboratories as
learning tools than she did on their value as motivators; however, as means of motivation for her students to engage in science learning, Lane believed that laboratories could enhance her students’ interest, thereby supporting her efforts of teaching scientific and real-life skills and verifying lectures.

*Laboratories as motivators.* For Lane, the utility of laboratories for motivation was secondary to their utility for learning; however, she did suggest that fun laboratories motivated her students to engage in laboratories. While fun was not her primary concern, it did play a pivotal role in her beliefs. For instance, when making a list of things that she had learned about laboratories (10/10) during her first few weeks as a teacher, Lane stated that she should “try to incorporate labs into lessons often” because “students almost always enjoy ‘putting their hands on’ something they’re studying.” In another example, she referenced a laboratory on dialysis and diffusion, stating that “they really like that lab. And I think they understood what was happening as well as it being enjoyable for them and exciting” (Interview, 09/22). She thought the liver laboratory also caught her students’ attention. In this case, the liver laboratory was fun “because it was gross” (Interview, 09/22). While fun laboratories as motivation were of secondary concern, she believed that they intrigued her students and resulted in greater interest in laboratory (Interview, 09/22).

The following excerpt from the natural selection laboratory is evidence of Lane’s use of humor to make laboratories fun:

Lane states that they will be going outside to better understand how natural selection works. She explains that “worms, particularly earthworms are a delicacy in the Cannon family.” She tells her students that they will be using their fingers to dig up some of the worms. [Several students squeal]. “Now the ones that I
don’t use tonight for our spaghetti supper, I’m going to be using on Friday when we go fishing so I want you to do a good job digging them up. We’re going to connect these earthworms to natural selection and what we’re doing today, so let me go ahead and pass out our labs.” (Observation 01/13)

Introducing the laboratory as a humorous story was an effective way of grabbing her students’ attention. She used humor following this laboratory as well when she awarded her students based upon the number of “worms” that they had collected for her spaghetti supper. Handing out certificates with each award, she stated that the group that showed the best worm catching talent got the “early-bird award” and the group that got the least amount of worms received the “do-do bird award” (Observation, 01/13). Also indicative of Lane’s belief of the utility of fun laboratories for learning, she wrote the following in notes to me regarding a urine analysis pedigree laboratory that I had shared with her: “Thanks for the ‘Pee’ lab. I’m sure it will be a fun one (& educational☺)” (Observation, 11/18). Lane clearly considered fun as a motivator for laboratories but it remained secondary to her emphasis on laboratories as learning tools.

Beliefs About Structure

Like Caroline and Jake, Lane relied on procedures to structure her laboratories. This practice is not uncommon for beginning teachers (Brickhouse & Bodner, 1992; Bryan, 2003; Gardiner & Farrangher, 1997; King et al., 2001; Simmons et al., 1999; Tobin, 1986), who find comfort in textbooks (Brickhouse, 1990; Tamir, 1989) and are often preoccupied with the technical details of laboratories (Champagne, 1990). Lane’s beliefs about the structure of laboratories supported these studies and concerned (a) her definition of laboratories and (b) her use of directions and questioning as assessment as means of procedural control.
Lane’s definition of laboratories. Lane believed that both student-centered and teacher-directed laboratories were beneficial to her students. For instance, she stated that:

At the beginning of the year, we did the radish seed experiments where they designed their own lab. Well, that’s a good inquiry-based experiment…they can design their own lab, come up with an experiment, write down procedures that they made up themselves, versus today when I wanted them to see the difference between freshwater cell and one in salt water. I wanted them to see the differences between those. So instead of having them design that lab today, I thought it was more beneficial for them to kind of follow the steps today. (Interview, 09/22)

Lane found teacher-centered laboratories beneficial and used them as her primary source of laboratory engagement; however, throughout the study she espoused student-centered beliefs.

Similar to Jake, Lane struggled with the differences between laboratories and activities and expressed this when she defined laboratories and activities during an interview:

I think probably to me, a lab would be using information and manipulating it, looking at it in a different angle, using equipment, constructing information based on basic concepts. An activity to me, I guess, would be more, like they are playing with the concept but it is still not really clear. I think there is, you know, the things that could be maybe considered as both, but to me more of an activity would be reinforcing concepts that you have already learned, and not really manipulating that and produce data, things like that or maybe like an engagement type tool where one activity to get them interested in a topic. So I guess the main difference then would be, and I am not sure you know what I told you at the beginning of the year, labs using equipment in the science classroom to, or not
necessarily even equipment, just to produce new data, manipulate ideas, construct new ideas. Also reinforcement, but going beyond reinforcement. (Interview, 10/12)

She found the line between her definition of laboratories and activities to be blurred (Interview, 12/10), but focused her definition of laboratories on scientific skills. Her awareness of this struggle surfaced often as evidenced by the following statement: “I have a feeling that you’re going to ask me about the difference between activities and labs today” (Observation, 12/10), which revealed her belief that the laboratory to which she invited me fit her definition of an activity better than her definition of a laboratory. Primarily, Lane invited me to and conducted what she defined as laboratories during which she engaged in detailed, teacher-centered laboratories that included few elements of inquiry.

*Control as structure.* Lane, like Jake, utilized laboratory procedures as a means of controlling student engagement and learning. Lane began each laboratory with a few minutes of review of prior course material that included topics like classes of organic compounds (Observation, 09/08), enzymes, pH, and activation energy (Observation, 09/10), phases of mitosis (Observation, 10/20), pedigrees (Observation, 11/18), and natural selection (Observation, 01/13). Following the review, She introduced each laboratory and asked that her students to develop their hypothesis for that day’s laboratory, based on their prior knowledge (Observation, 09/08; 09/10; 09/22; 10/16; 10/20; 11/12; 11/18; 12/10; 01/13; 01/21). These pre-laboratory steps suggest that Lane’s beliefs about the structure of laboratories can further be understood as beliefs about procedural control. Lane focused on giving clear directions and asking questions during laboratories to determine understanding in an effort to control her students’ laboratory engagement and learning.
Lane spent approximately five and a half minutes at the beginning of each laboratory giving directions, and her students spent an average of twenty-nine minutes conducting each laboratory. She believed that clear directions and infrequent student questions were indicative of an effective laboratory. Therefore, she prided herself on days when her students’ questions were rare because she felt like they had grasped the laboratory’s directions (Interview, 08/04). Lane believed that clear, concise directions were central to a successful laboratory. Most laboratories were self-explanatory, with directions that Lane briefly reviewed and the students followed. On only one occasion, during the “baby food lab” on testing organic compounds in foods (Observation, 09/10) did her directions include detailed verbal and visual guidelines in addition to the provided written directions. Upon reflection, Lane suggested that the detailed directions were necessary because she felt that her students would get far too confused by the shear number of steps. Interestingly, this laboratory resulted in the greatest number of student questions and confusion. According to a professor that worked with her during her reflections course, Lane used this same laboratory during student teaching and encountered many of the same challenges. Lane described this experience in the following interview excerpt:

When I was student teaching, we did a food lab where we looked at different things in biochemistry like proteins and DNA and fats and stuff – we used different indicators to determine which unknown foods had different things in it – like macaroni and baby food and the students would test it to see if it had high protein content or fat content and so on and so forth. And [sighs] it didn’t go very well [laughs] when I was doing it because I think the directions that I had were not very clear – they didn’t explain it very well and so I know that I learned a lot from that. It was just REALLY complicated and I don’t think I spent enough time
explaining the procedures to the students beforehand and so in the last part it was chaos. I think that day really stood out for me because it just – things had been going so smoothly for me during student teaching and all of a sudden it was like “AHH! What am I going to do?” You know, and it was a challenge for me I guess to try and regain control of the situation and I think I just learned – took a lot away from that day as far as having patience and really planning out the lab a little bit better than I had.

Lane, like Jake, gauged the success of her laboratories on completion and the number of technical questions that her students asked. For example, when asked how she can tell if a laboratory was effective, Lane replied, “I think it’s effective if students can complete the lab and don’t have so many minor and technical questions during the lab. I think it’s successful if students can go through the lab themselves without lots of input from me and lots of help from me” (Interview, 08/04). In this way, Lane revealed beliefs about the structure of laboratories via the utility of laboratories for limiting student confusion as the result of clear directions.

Interestingly, Lane’s students asked more questions during the two laboratories with the most detailed verbal directions (Observation, 09/08; 09/10). Following the first observation (09/08) Lane appeared to analyze the amount of directions that she gave and the confusion that the students exhibited:

I think I spent so much time in class, showing them the different tests that they don’t have a lot of time – I spent two days on it – I don’t think that much time is – for me to give those directions for twenty or thirty minutes of class and students try to perform the test and sometimes they still get confused, and then spending an
extra day on it as well for them to write it up and figure out what was going on.

(Interview, 09/22)

In this statement about the baby food laboratory, Lane showed that she was aware that she had given extensive directions to her students and was frustrated that even after thirty minutes of directions her students still struggled with the detailed steps of the laboratory. By repeating the baby food laboratory in much the same way she used it during student teaching and by maintaining the necessity of thorough directions, Lane exhibited a reliance on procedures despite contradictory evidence of student confusion. This experience reinforced Lane’s views on how much direction students need during laboratories rather than causing her to investigate why her students remained confused.

In contrast to the lengthy directions in the baby food laboratory, the plasmolysis laboratory was an example of a lesson in which a short list of directions was given and few student questions were asked. This laboratory was used to verify lectured material on hyper-, hypo-, and isotonic solutions and included limited verbal directions. The written directions were as follows:

1. Prepare a wet mount of an *Elodea* leaf using distilled water, a microscope slide, and a coverslip. View the slide under low, medium, and high powers. **Draw** at least 5 cells under the highest power possible. Don’t forget to include magnification. Also, **label** the chloroplasts and cell walls.

2. Observed the *Elodea* leaf using the 10% salt solution. You can do this in two ways:
   a. Create another wet mount with a new leaf and the 10% salt solution
b. Using the slide you already have, irrigate the saltwater underneath the coverslip. To do so, place several drops of the 10% salt solution on one side of the coverslip. Using a paper towel to then ‘pull’ the saltwater underneath the coverslip and across the leaf.

Again, **draw** at least 5 cells under the highest possible power. **Label** the chloroplasts and cell wall. (Observation, 09/22)

These clear directions appeared to be easy for students to understand and follow as evidenced by their on-task behavior during this laboratory. Upon observation, it was apparent that they had already been exposed to microscope manipulations prior to this laboratory and were able to engage in this laboratory based upon these directions. When asked about the importance of clear directions to laboratories, Lane stated that:

> I think if you try to stop a lab, you know, to give directions they’re either working or talking to their partner about something and they don’t care. So I think at the beginning you want to make sure that you, they know the information that they need to know… I think giving basic directions are good, but I didn’t want to give them too many directions, I didn’t want to tell them how to do it. I wanted them to figure that out, because that is where a lot of them have problems…they are kind of the guinea pigs and then by fourth and fifth, like okay, I know what I need to say and what I need to make sure that I go over. (Interview, 12/10)

Lane recognized that giving clear directions was integral to accomplishing her classroom goals, but that **telling** them how to do the laboratory placed too much emphasis on her and took away any necessity for her students to think. How, when, and why Lane gave directions became
central to her developing beliefs about teaching in the laboratory. When asked what she had
learned so far that semester about laboratories, she stated:

One of the main things that I found, and I’m trying to improve on this is giving
clear directions, whether I’m speaking those directions before the lab, if they’re
not very clear on the handout or they’re very clear, so the students can read step-
by-step, what they’re expected to do. Because in a few labs in the beginning
maybe, I wasn’t as clear in my directions and there are so many questions and I’m
trying to help them find out what they’re learning – at the same time, trying to
answer fifty thousand questions at one time. So that’s probably one of the main
things that I’ve learned about labs so far is either give clear verbal instructions or
have it designed so that there aren’t as many questions for students to be confused
by – so they’re REALLY concentrating on following the steps and learning what
they’re supposed to be learning in the lab. (Interview, 09/22)

For Lane, showing and telling were not equivalent to written directions as evidenced in the
following statement taken from her October Impressionist Tale: “Students were given the task of
figuring out the surface area, volume, and distance from the center of each ‘cell’ to the outer
membrane (side). I did not tell the students how to do this.” This same laboratory included
detailed written directions on how to make these calculations and Lane announced that she
would “like for you to think through these for yourself first – how can you figure out surface
area, volume of the cells. I’d like for you to think through the ratios. You can use your book as a
guide – it should take you through how to do those if you don’t understand exactly. And then if
you have questions, ask me” (Observation, 10/16).
Lane’s beliefs about the structure of laboratories for procedural control also included the use of questioning as a means of assessment. For instance, during a laboratory on reagents and food nutrients, Lane’s conversations with her students started with “how are you doing?” to gauge student progress, and then she asked what they found, specifically focusing on what each reagent tested for, i.e. “iodine is a test for…?” (Observation, 09/08). This type of questioning was common to all of her laboratories—brief stops with pairs of students to make sure that they were working and understood the laboratory. She indicated that this type of questioning also helped her gauge the success of a laboratory:

Usually when I’m walking around and I’m asking students questions, if they understand the concepts and understand what’s happening, usually, that’s kind of my main indicator. Even the questions that they write down and answer, I’m not exactly sure that they understand – they could’ve gotten them from their partner or someone else in the class. Usually, when I’m walking around asking individual students, “What do you see happening? How is this related to osmosis?” If they can explain it to and they understand what’s happening then I think it’s successful. (Interview, 09/10)

She prepared her students for this type of assessment at the beginning of each laboratory. For example, Lane stated that “if you have any questions during the lab, I’m going to be walking around, to see what you’re what you’re seeing – I’m going to ask you to identify the different phases under the microscope for me and tell me what’s happening during those phases so I’ll be walking around doing that during the lab” (Observation, 10/20).

Lane’s use of questioning was reinforced by her mentor teacher who noted that, “this was an excellent and challenging activity for a gifted class. Ms. Cannon circulated around and
checked on students as they worked. She asked them challenging questions as they tried to work through the problem” (10/16). In this case, in addition to procedural control, her questioning was also used to encourage her students to make observations. For instance, Lane did each step for the liver laboratory as she explained it, and then asked for a volunteer to help her light the splint and put it in the test tube. She stated that once combined, the mixture foamed. She then asked her students the following questions: “What is happening? What is a product of the breakdown of hydrogen peroxide” (Observation, 09/10) all in an effort to guide their data collection.

In addition to questions that gauged progress and encourage observation, Lane asked questions that required prediction skills. For example, after engaging in a diffusion laboratory in which a 15% starch and 1% glucose solution is placed in dialysis tubing and immersed in a water and iodine solution, students were asked “What results would you expect if the experiment started with glucose and iodine solution inside the bag and only starch and water outside?” This question required students to have an understanding of the size of starch and sugar molecules and the process of diffusion so that they could respond to a scenario that they had not observed (Observation, 09/22). Lane’s students answered questions following each laboratory and used reasoning to reflect on their results; recording results in their laboratory notebooks. However, the reflections were not always student-generated. For example, on September 8th, after engaging in an organic compound laboratory in which the students tested baby foods to gauge their content, students’ reflections were given to them by Lane. During the thirteen minutes that Lane gave the students directions, she showed them each step. In the final assessment of the baby food laboratory, the students had been asked to explain why salt water was used in each test. They had been told during their directions that the salt water acted as the control (Observation, 09/08). In another example from her August Impressionist Tale, Lane wrote about a microscope laboratory
from the perspective of a twenty-dollar bill that the students saw at the end of the period. This laboratory contained strictly recall questions and did not require critical thinking or reasoning skills.

In addition to questioning during laboratories, Lane used questioning before and after laboratories to relate information to lectured material. The following excerpt from fieldnotes typified exchanges that took place during laboratory preparations, in which Lane used questioning to review lectured material:

Lane: What were those four classes of organic compounds that we talked about last Friday?

Students: Proteins, carbohydrates, lipids…, and…what was the fourth one?

Lane: Proteins, carbohydrates, lipids, and…what was the fourth one?

Lane: Nucleic acids, right?

Lane: So we’re going to be testing for the presence of starch. Starch is a…?

Students: Carbohydrate.

Lane: And we’re going to be testing for the presence of sugar. Sugar is also a…?

Students: Carbohydrate

Lane: Carbohydrate

Lane: Fat, which is a…?

Students: Lipid

Lane: Lipid

Lane: And proteins. (Observation, 09/08)

This example suggests that Lane’s focus during lecture reviews was on recall and on science as a set of discreet facts. This view of science is in sharp contrast to her espoused emphasis on the
nature of science in her classroom, but supports her beliefs about control. Lane’s beliefs about the purpose and structure of laboratories focused primarily on laboratories as means of controlling procedural steps. This use of laboratories created inconsistencies with her understanding of the nature of science. Next, I describe how these inconsistencies revealed a tension in her beliefs. I examine the influence of her teacher-centered colleagues and her beliefs about her students conditioning to there being one “right” answer on Lane’s beliefs about procedural control.

Framing Lane’s Tension

Like Jake, Lane struggled with the notion of control. The inconsistencies in her espoused beliefs and classroom actions revealed tensions that resulted in a control frame. The tensions that emerged for Lane were the result of the influence of her colleagues and her students who focused Lane’s actions on procedural control, in contrast to her espoused desire to enact laboratories based on her understanding of the nature of science. Because Lane struggled with how her student-centered beliefs conflicted with her teacher-centered classroom actions, she faced dilemmas with the amount of direction she should give her students. In her lesson plan for the liver laboratory, she emphasized in a note to herself to “briefly explain to students what they will be doing in lab” (09/10). She followed this plan with the following statement to her students during the liver laboratory: “Today what you’re going to be doing is following through the lab. I don’t really want to explain it. I want you to read it for yourself” (Observation, 09/10). However, Lane did explain each step. More often than not, she chose more detailed directions to lead her students through their laboratory investigations.

Lane’s espoused the belief that science was a “wheel that you hop onto at any point” (Interview, 08/04) rather than as a specific method that one follows step-by-step. She also
espoused the belief that laboratories should be “student-centered discovery learning” (Interview, 08/04). Lane’s espoused beliefs about laboratories appeared to be rooted in her prior experiences as a science learner and teacher. Positive experiences in high school and during student teaching led Lane to believe that science is best learned in the laboratory. However she faced tensions with whether or not biology was conducive to student-centered, discovery learning as evidenced in the following statement: “I think especially in some other disciplines like physics, you can give people circuits and they can kind of figure it out – just different things – it may be easier to do in other science disciplines other than biology, but I think we have to try too” (Interview, 08/04). This struggle reveals a foundational aspect of her beliefs about control. Lane believed that laboratories were ideally student guided; however, she thought that the reality of student-guided laboratories might be a reach for her as a biology teacher and as a first year teacher (Interview, 08/04).

Lane’s classroom actions about control were influenced by her mentor teacher, who also had a more subtle influence on Lane’s espoused beliefs. Because her mentor teacher played a significant role in guiding Lane as a student teacher and first-year teacher, her espoused beliefs appeared to come into concert with those of her mentor. They maintained a mentoring relationship as Lane began teaching in the room next door and Lane’s mentor guided her towards more teacher-centered, detailed laboratories that Lane might not have otherwise chosen. For instance, in contrast to Lane’s beliefs that she should incorporate inquiry elements into her laboratories, Lane’s mentor suggested during their planning meeting, that conducting inquiry investigations was not a realistic expectation of teachers in Fairfield County, due to the pressures put on them to cover a large amount of course material (Planning Observation, 10/27). This emphasis was evident in Lane’s classroom actions about procedural control in laboratories, even
though Lane maintained relatively stable student-centered espoused beliefs based on her understanding of the nature of science throughout the study. Lane did not have a lot of freedom during student teaching to engage students using her own material. In fact, when asked to describe her best day teaching, Lane illustrated a day during an ecology unit in which she was able to try some creative and interesting demonstrations, separate from the prescribed lessons:

We did an activity where they went mining in cupcakes for M&Ms and we talked about the benefits of mining and how things can’t really be replaced the way they were. I shared some data with them from mining and we talked about oil spills and the history of oil spills and what they use to clean up oil spills. And so, that was really a good day for me because it allowed me to do some things that I wanted to do with the students and kind of use some of my own material which I didn’t get to do a lot when I was student teaching. (Interview, 08/04)

Including her own creative aspects in this laboratory on mining gave her a sense of accomplishment. Despite not having a lot of freedom during student teaching, Lane experiences planning during that time were valuable to her. For instance, she stated that:

…when I was student teaching, I used a lot of labs that every other member of the department does – that’s kind of what we do here at Stony Creek. I don’t think I really sat down myself and read through it the way that I should have and thought out possible student problems and what exactly they need to know. So I think in lab preparation, I need to spend more time thinking about what is it exactly that students need in order to do the lab? What things can I leave out that they should be able to infer on their own – or you know, come up with on their own that won’t
leave them out in the dark as far a instructions are concerned – but will be more of their experimenting and openendedness. (Interview, 08/04)

This guidance from her colleagues gave her confidence to engage in laboratories with some background, but ultimately also influenced her use of the same laboratories that her colleagues used in an effort to ensure that “if a student moves from class to class they’re kind of doing the same thing. Also if parents have complaints about one teacher or what’s being done in one classroom, it’s something that’s been decide upon by all teachers. So I guess to have that support that all the teachers approve it and that’s what we’ve all decided to do” (Interview, 08/04). This did not mean that they were required to do exactly the same lessons; they just needed to stick to the schedule. For example, Lane stated that:

All of us have taken several different units to plan and then we’re all just kind of sharing information right now and kind of putting input into what we should do in each, but like one person is responsible for the test or a general test – of course we can change it if we’d like – we don’t have to use it if we don’t want to. That’s what we’ve been doing right now. For right now I know for the first unit, we’re pretty much using the same lab across the board, but if we don’t want to, we don’t have to. And there’s several teachers here who just kind of do their own thing. So, we have that choice and no one’s going to get mad [laughing] if we decide not to use what the other person planned. (Interview, 08/04)

For a first year teacher, what everyone else is doing tends to be what you do because most beginning teachers feel a need to belong (Eisenhart et al., 1988). Despite the influence of her colleagues, Lane maintained fairly stable student-centered beliefs about laboratories because, ideally, she believed that student-guided laboratories:
give them choices and kind of give them options. I know that we talked a lot in our methods and curriculum classes about how students should be kind of given the opportunity to design the lab themselves, not just everything just laid out step by step for them. I think ideally, that’s what a lab should be like, but there is a definite conclusion or a definite goal that you’re trying to reach. (Interview, 08/04)

However, as a first year teacher, she believed that she faced barriers to her ideal plan for laboratories as expressed in the following statement:

I have learned that more units are better suited for hands-on type labs than others, that are easier to, that have hands-on labs and using…I think with all of the things that we are required to cover, with all the different QCC’s and standards that we are required to cover, and with things that happen at school, the testing and things like that, it is just hard to continue a lab like that over a period of months, because we don’t spend a month on any one unit, you know DNA, it is all related, but strictly speaking of genetics - and so to try and carrying it out for months, you would have to introduce those concepts a month ahead and then hopefully by the end of the unit, you would have it finished. So I am not saying I would never do that, I just think that it requires more time, the students get frustrated, and I just didn’t have enough time to plan an extended lab. (Interview, 12/10)

Due to the nature of her experiences planning lessons with her colleagues, Lane’s use of laboratories focused on teacher-provided directions. Her mentor teacher had an especially significant impact on what laboratories Lane chose to do and how she chose to do them. These
teacher-centered laboratories were in contrast to Lane’s understanding of the nature of science and therefore, created tensions in her thinking.

Lane’s teacher-centered classroom actions were also influenced by her gifted (as defined by Fairfield County Schools) students’ need to have the “right” answer. She described this in the following interview excerpt:

I know with my gifted students, a lot of them are such perfectionists, they want to make sure that they don’t do anything wrong and they want to please me to get a good grade. So I think that’s one of the reasons for them that I have so many questions if it’s not very clear what I want them to do. And I think also, they’re not use to being given something and figuring out how it should work as well. I think they’re use to step-by-step instructions and so it’s kind of a dilemma…you want them – it should be inquiry and it should be kind of designing their own and planning their own, but at the same time, when you don’t do that, they’re so confused about what they should be doing a lot of times – it doesn’t work out well. (Interview, 09/22)

Her view of her student’s need for “step-by-step” instructions fed her developing beliefs about procedural control. She attributed her students’ reactions in laboratories to their past experiences in classes in which they were not encouraged to think and reason. She stated that:

I think in a lot of their classes, they are not encouraged to do that in a way. You know you kind of feed it to me and I will regurgitate it. Like today, they are like oh how do I do this, how do I do that; that is something to think about, what do you know, what are you trying to know, how to get there, you know. And I think in a lot of classes and in a lot of the other, maybe in middle school as well, I don’t
know, they just weren’t really encouraged to do a lot of that, to get them to say oh well this requires some effort on my part, I think is pretty difficult because they just want to get it over with. (Interview, 12/10)

Lane’s students frequently checked their answers as they worked in laboratory (Observation 09/08; 09/10; 09/22; 10/16; 10/20; 11/12; 11/18; 12/10; 01/13). For instance, during the first laboratory on organic compounds, following very detailed directions that included both verbal directions and physically showing each step, students in one group called Lane over to verify positive test for sugar, showing her the test tube. Lane told this group that the test, if positive, would turn white or brown (Observation, 09/08). In another laboratory on mitosis in which directions were written in the laboratory handout that each student had, one student asked if they should’ve counted a hundred plus cells in interphase and Lane confirms (Observation, 10/20). Additionally, a laboratory on genetic traits, students occasionally, asked Lane to verify if their eyelashes are long or their eyes are round (Observation, 11/12). Therefore, engaging students in more self-directed laboratories or parts of laboratories resulted in a tension for Lane that she found difficult to overcome.

In the case of Lane’s tension, she encountered what Caroline and to a lesser extent, Jake did—the desire to incorporate student-centered aspects into their laboratories, met by student and collegial resistance. Lane maintained student-centered beliefs throughout the study and with more time teaching and opportunities to reflect on her actions, I posit that she may begin to use inquiry-based laboratory elements to a greater degree. However, like Jake, Lane remains in an environment that fosters her use of teacher-centered laboratories and will need to experience perturbations in her thinking for changes to occur. Additionally, Lane’s emphasis on following directions and recall of facts revealed that she held a naïve view of the nature of science and may
find incorporating more student-centered aspects into laboratories difficult. Lane needs time to develop a more mature understanding of the nature of science in order to engage her students in laboratories in which the generation of their conceptual understanding through laboratory investigations takes place. Ideally, reframing for Lane would begin with a deeper understanding of the nature of science and knowledge of how students learn.

While Lane did not appear to confront her tensions during this study, on a number of occasions, she requested the opportunity to discuss the study’s findings as a means of improving her teaching. I expect her willingness to improve her teaching and reflect on her practice will benefit her and her students.

In the chapter that follows, I discuss the similarities and differences in Caroline, Jake, and Lane’s cases via a cross-case analysis. I tie the discussion to relevant literature for each of their beliefs and the tensions that arose.
CHAPTER SEVEN
DISCUSSION

In order to better understand first-year secondary science teachers’ beliefs about laboratories, I engaged in this study with the following central question guiding my work: *What are first-year secondary science teachers’ espoused beliefs and classroom actions regarding the use of laboratories in science teaching?* In this chapter, I compare Caroline, Jake, and Lane’s beliefs and the tension(s) that emerged for each due to inconsistencies in those beliefs. I start with their beliefs about the purpose of laboratories as learning tools and motivators and then move to their beliefs about the structure of laboratories. While Caroline, Jake, and Lane held many similar salient beliefs about the purpose and structure of laboratories, the emphasis that each placed on their beliefs was unique.

Beliefs About Purpose

The definition of what purpose laboratory teaching should serve has been clearly laid out in the vision of efforts to reform science education in the United States (AAAS, 1990; NRC, 1996; 2000). These initiatives describe laboratory teaching as opportunities to achieve scientific literacy through the investigation of questions of interest to students, manipulation of variables, and collaboration with peers. In addition, the National Science Education Standards recommend that teachers:

- orchestrate discourse among students about scientific ideas;
- challenge students to accept and share responsibility for their own learning;
• recognize and respond to student diversity and encourage all students to participate fully in science learning;

• encourage and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas, and skepticism that characterize science.

(NRC, 1996, pp. 36 & 37)

This emphasis on the student’s role is integral to this study. In addition, both the national and state science teachers’ associations (GSTA, n.d.; NSTA, 1990) define laboratories based upon these reforms. Furthermore, reviews of the literature have concluded that over the last century, the purposes of laboratories have been: understanding of scientific concepts, enhancing interest and motivation in science, improving scientific practical skills and problem solving abilities, encouraging scientific habits of mind, and understanding the nature of science (Hofstein & Lunetta, 2003). In each of these cases, the common themes that emerge are of students actively participating in knowledge generation, guided by their teachers.

Caroline, Jake, and Lane espoused beliefs about the definitions of laboratories that paralleled the purposes set forth by the reform initiatives (AAAS, 1990; NRC, 1996; 2000) and the teachers’ associations (GSTA, n.d.; NSTA, 1990)—that students learn science by doing science and that student-centered laboratory investigations were the most effective ways to achieve this. Additionally, they believed that laboratories enhanced student motivation. However, their classroom actions were often in contrast to their espoused beliefs. Their beliefs about laboratories as teacher-centered places to do science suggest that they believe students learn entirely by doing, but this focus forsakes the minds-on nature of science learning. The beliefs of this study’s participants emphasized almost entirely, skill building and failed to recognize science learning as student-generated conceptual understanding. Even Lane, who
frequently discussed the nature of science, held naïve conceptions of what that means. Caroline, Jake, and Lane each lacked the epistemological knowledge to enact truly student-centered laboratories and missed the implications that their beliefs had on student learning.

One important focus of the national science education reforms is the generation of knowledge and conceptual understandings by science students, yet all three participants primarily valued laboratories as verification tools and their classroom actions supported this view. Caroline, Jake, and Lane used “cookbook” laboratories as learning tools and motivators, through which they sought to teach science skills and increase student interest. They each espoused beliefs that laboratories should teach their students how to think like scientists think, but in all three cases, failed to accomplish this.

Laboratories as Learning Tools

As learning tools, the participants in this study believed that laboratories were useful for teaching students skills and for verifying lectured course material. Caroline, Jake, and Lane espoused beliefs and classroom actions regarding the value of laboratories for teaching their students real-life skills. They each believed that their students needed information beneficial to them outside of school that they could teach via laboratories. For instance, Caroline placed value on teaching her students to read and follow directions because she believed that this skill would be invaluable to them in the workplace. Caroline also emphasized the usefulness of mathematical skills in her laboratories and the real world. Jake focused his efforts on science content that might interest his students and be useful to them. For example, he taught a unit on radiation and used it as an opportunity to discuss cancer. He used the students’ experiences to make connections with science. Lane used laboratories to make connections between laboratories and
their real-life experiences. For instance, she referred to the flammability of oxygen during the liver laboratory, pointing out the signs on oxygen tanks asking people not to smoke.

Caroline and Jake used laboratories solely to follow lectures in an effort to show their students what they had been discussing in class. They both believed that by seeing it for themselves, students were able to better learn the lectured material. Lane also used laboratories to “make the abstract concrete”, but unlike Caroline and Jake, she occasionally used laboratories to introduce a topic as a means of sparking her students’ interest.

Each of the participants in this study had a vision of how they were supposed to teach science. As a result, their espoused emphases on student-centered laboratories as valued by the national reforms were not surprising. Additionally, their experiences as science learners that led them to become science teachers were described as student-centered. It was also not surprising that each enacted teacher-centered beliefs despite these experiences. There could be several reasons for this, but I suspect that four were most salient. First, Caroline, Jake, and Lane likely did not possess the epistemological knowledge necessary to translate student-centered beliefs into classroom actions. The development of such knowledge is begun during science methods courses, but is a heavy burden to place on a single course. It takes time, support and appropriate professional development experiences to achieve this goal. Second, it is likely that most of their science experiences were traditional, didactic lessons. Caroline, Jake, and Lane’s science teachers probably experienced traditional science as students and as preservice teachers and therefore, taught that way. Because I asked them to describe teachers and laboratories that stood out for them, perhaps they best-remembered those that included aspects where they got to see and do science. However, overwhelmingly, their experiences in K-12 and college would likely have included seeing and doing science in a lectured-based science where laboratories were used
as verification tools. This apprenticeship of observation (Lortie, 1975) is a vicious cycle that is
difficult to break. Third, teachers tend to teach they way they learned best (Czerniak & Lumpe,
1996). It is therefore, likely that Caroline, Jake, and Lane incorporated their newer standards-
based beliefs into their more stable beliefs about teaching and learning that resulted in traditional
classroom teaching, while maintaining at least some degree of espoused beliefs about the value
of student-centered teaching and learning. Fourth, all three participants taught laboratories that
they received from their colleagues. In addition, all three sought their colleagues’ opinions and
support when planning for, implementing, and assessing laboratories. The laboratories that they
used were seen as “survival tools” that they would modify as they got more experience with
teaching.

Laboratories as Motivators

Like teachers described in Hodson (1993b), *Re-thinking old ways: Towards a more
critical approach to practical work in school science*, Caroline and Lane espoused the belief that
stimulating their students’ interest and enjoyment in science was central to their laboratory
teaching. They believed that laboratory learning was fun and therefore should interest their
students in learning science. Caroline put the greatest emphasis on fun as an outcome of her
laboratories, a choice which often created tension for her in the face of student apathy. Her
efforts toward developing her students’ enthusiasm for science by using laboratories supports the
findings of Eisenhart et al. (1988), that building student enthusiasm is more important to teachers
than teaching the specific subject matter. Jake and Lane placed greater emphasis on learning
skills in the laboratory than Caroline, but Lane’s beliefs about the utility of laboratories as fun
ways to motivate students remained integral to her beliefs about laboratories. Jake did not
emphasize fun when discussing laboratories, choosing instead to focus on the utility of grades as motivators.

In addition to fun, Caroline used friendly competition during laboratories to engage her students. I saw no evidence of the use of competition in Jake’s laboratories and very little in Lane’s (Observation, 01/13). Interestingly, these findings support research by Stuart and Thurlow (2000) who stated, “Asked if the use of competition is an effective teaching strategy, the majority of preservice teachers responded with a resounding No. However, some said that they found competition invigorating and very motivating” (p. 117). In light of this, the emphasis that Caroline placed on competition is not surprising. As evidenced by her classroom actions, she too found the use of competition invigorating and very motivating.

In addition to fun and competition as motivators, grades served as means to stimulate student participation in laboratories. During laboratories, Caroline offered extra credit and Jake offered open-book quizzes as incentives to work. Caroline also allowed her students on occasion to replace low grades with work, which she believed motivated them. For all three participants, student reactions to laboratories suggested that they were concerned about grades due to their focus on getting the “right” answer. Caroline believed that her students failed to engage in critical thinking or reasoning in laboratories because they had never had to do so outside of her class and focused instead on finding the “right” answer to complete the laboratory. Jake perceived his students focus on the “right” answer as a lack of confidence on their part, evidenced by their frequent fact and procedural checking during laboratories. Lane did not emphasize grades during her laboratory teaching, but it was apparent that her students’ interest in grades served to motivate them.
I expect, that like their memories of prior traditional science learning, Caroline, Jake, and Lane remembered laboratories that they engaged in as students, which best fit their learning styles. Returning to the idea that teachers teach the way they learn best (Czerniak & Lumpe, 1996), Caroline likely preferred laboratories that were fun, a theme that can be found in her narrative when describing one of her high school teachers. Jake, learned best in traditional, no-nonsense, controlled laboratories. This theme can be seen in his narrative of one of his high school teachers. Lane’s focus on learning leads me to believe that as a learner, she prefers laboratories with clear directions that include elements which encourage critical thinking. Each of my participants motivated their students in very different ways. Encouraging them to enjoy science, complete the laboratory, or learn science content, Caroline, Jake, and Lane chose ways to motivate their students that I suspect motivated them as students.

Beliefs About Structure

The structure of laboratories for each of the participants in this study supported their beliefs about the purposes of laboratories for science teaching. Differences and similarities in how they defined and used laboratories are described below.

Definitions of Laboratories

Caroline, Jake, and Lane defined laboratories as opportunities for their students to see and do science that supplemented other aspects of their teaching. When describing student-centered learning, they each emphasized movement (doing science) and scientific skills such as observing, recording, and analyzing data. For Caroline, student-centered laboratories were defined by doing—having and manipulating data, observing, writing, and recording. Jake viewed student-centered laboratories as opportunities for his students to “play around” with concepts because he believed that they learned better when they were able to get their hands on it. Lane’s
beliefs about student-centered laboratories concerned using and manipulating information and equipment and constructing information based on basic concepts. None of the three participants included in their definitions of student-centered laboratories the concept of student-generated knowledge. They each discussed laboratories as opportunities to see and do science.

Caroline, Jake, and Lane also defined laboratories in this study by choosing which lessons to invite me to observe. By inviting me to primarily “cookbook” laboratories, each participant revealed their beliefs about laboratories as teacher-centered, procedural experiences. Jake included in his definition, the first-semester laboratory practicum. Lane was the only one to focus her definition of laboratories on her understanding of the nature of science, a belief that was revealed in her espoused and to a lesser extent, her classrooms actions. Despite the differences in their definitions of laboratories, each participant in this study felt strongly that engaging in laboratories enhanced their students’ science learning and motivation.

Another way to view the differences in their definitions of laboratories returns to their specific purposes for using laboratories. Caroline used laboratories primarily as motivation tools. To encourage her students to learn, she used fun laboratories and competition. Whereas, Lane wished for her students to have fun, but her primary reason for using laboratories was to “make the abstract concrete”, focusing more on laboratories as learning tools than motivators. Unlike Caroline, Lane and Jake’s beliefs about the purpose laboratories ultimately centered on procedural control. Their desire for controlling laboratory procedures outweighed enhancing meaningful laboratory learning. In addition to procedural control, Jake also used aspects of laboratories for behavioral control.
Research supports the idea that teachers’ espoused beliefs and classroom actions are often in contrast (Brickhouse, 1990; Brickhouse & Bodner, 1992; Bryan, 2003; Gardiner & Farrangher, 1997; Haney & McArthur, 2002; Haney et al., 1996; Luft, 2001; Simmons et al., 1999; Thomas et al., 2001; Yerrick et al., 1997). Their beliefs are also “not necessarily consistent with the literature about best practice in teaching” (Lumpe et al., 2000, p. 276). Compounding, or possibly explaining this mismatch between espoused beliefs and classroom actions is Welch et al.’s (1981) assertion that teachers often feel ill-prepared for student-directed learning styles. The realities of being a new teacher in a science classroom add to this problem (Luft & Patterson, 2002; Salish I Project, 1997) and often challenge teachers deeply held, personal beliefs. As a result, teachers likely adhere to their most stable, oldest beliefs (Bryan, 2003; Haney & McArthur, 2002; Richardson, 1996; Tobin, 1990). Caroline, Jake, and Lane espoused beliefs that as first year teachers, they would need extra help to implement student-centered pedagogies and stated that the reality was that they felt unprepared to do so. As first year teachers, they realized a pressure to try student-centered laboratories; however, the realities of their classrooms, their lack of epistemological knowledge, and the opposing pressure from many of their colleagues influenced their beliefs toward more teacher-centeredness.

All three participants in this study engaged in teacher-centered classroom actions to varying degrees. Jake gave detailed written and verbal directions at the beginning of each laboratory. Written directions in Jake’s laboratories were often short and concise, and were included on labsheets that all technical level students at Fairfield County High School were expected to copy fully prior to participation. These labsheets (see Appendix D) included the purpose, materials, procedures, safety precautions, and questions for each laboratory and students
were not allowed to engage in laboratories until they had finished copying these. In addition to
detailed written and verbal directions, Jake included demonstrations of each step of the laboratory
as he verbally reviewed them. His need to control his students’ behavior through laboratory
procedures despite his espoused student-centered, discovery beliefs, suggests that his beliefs about
the structure of laboratories are deeply rooted, core beliefs. Lane also utilized procedural control
during laboratories to guide student learning. On a few occasions, Lane also included
demonstrations in addition to the laboratories verbal and written directions. While to a lesser extent
than Jake, Lane’s need for control also appeared central to her core beliefs about science
laboratories.

Caroline, Jake, and Lane chose teacher-centered laboratories as their primary means of
laboratory lessons, but unlike Jake, Caroline and Lane often encouraged their students to explore
additional means of testing their findings in a number of instances. Lane expected her students to
develop hypotheses for each laboratory before beginning and included elements in some of her
laboratories that stretched her students thinking. Additionally, they both encouraged their
students’ reasoning in laboratories as they worked in cooperative groups to examine the
scientific phenomena under study.

The effort that each participant put towards engaging their students in laboratories
suggests that they valued them. As means of seeing and doing science, Caroline, Jake, and Lane
believed that laboratories allowed their students to learn through experimentation. Their beliefs
about what it means to engage students in science learning were markedly different from those
set forth by science education reforms. And as Simmons et al. (1999) discussed, beginning
teachers tend to translate their classroom experiences into visions of what good teaching and
learning look like. Caroline, Jake, and Lane have done so in this study in ways that are inconsistent with science education reform efforts.

Assessment of Laboratories

Caroline, Jake, and Lane primarily assessed laboratories through questioning to gauge progress and recall. In addition, they used data tables and questions on the students’ labsheets to ensure that their students participated in and completed the laboratory. They also used departmental laboratory practicum, but in none of the cases did they assess laboratory skills and knowledge, beyond that which could be evaluated in a multiple-choice format, on formal tests. Another area of assessment for all three participants was the way that they felt the laboratory went when it was over. Student response to questioning and feelings of accomplishment were the primary ways that Caroline, Jake, and Lane gauged the success of each laboratory.

Assessment has the potential to focus learning in the science classroom (Tobin, 1990). In fact, “there is an increasing tendency for assessment procedures to determine laboratory activities” (Hodson, 1993a, p.90). Test-driven school systems often result in rote learning of facts through teacher-driven laboratories (Tobin, 1990). In addition to reasons for the participants’ beliefs about the utility of laboratories to teach skills and stimulate recall, one additional may be Fairfield County’s test-driven system. It is therefore, no wonder then that Caroline, Jake, and Lane use laboratories that are teacher-driven as means of focusing on lectured facts. The beliefs are not considered desirable under the umbrella of the national reform efforts, but are understandable given their school system.

In addition to assessment driving the type of laboratories chosen, the type of tests used to assess science learning significantly impact “what and how students learn and where they invest their efforts” (Tamir, 1989, p. 66). Caroline, Jake, and Lane used departmental assessments and
county-wide test banks to evaluate their students’ knowledge of science. These tests used multiple choice questions and placed little emphasis on critical thinking and reasoning. Lane’s mentor teacher mentioned that Fairfield County’s focus on content coverage necessitates the use of this type of assessment (Planning Observation, 10/24). Testing as assessment did not emerge as a theme from the data; however, the influence of Fairfield County’s tests on the laboratories that their teachers use holds promise as a rich area of study.

The espoused beliefs that Caroline, Jake, and Lane held about the purpose and structure of laboratories were often inconsistent with their classroom actions. As a result, each participant experienced tension(s) in their beliefs.

Tensions

Despite different backgrounds as science learners, different experiences as science teachers, different grade levels and subjects taught, and different student populations, Caroline, Jake, and Lane held espoused beliefs that were remarkably similar at the surface. However, looking more deeply at inconsistencies in their espoused beliefs and classroom actions through their experiences as science learners and teachers revealed tensions in their beliefs that are quite different.

Caroline, Jake, and Lane espoused beliefs about laboratories as student-centered ways of teaching and learning science. And each saw laboratories as essential to their teaching. Lane focused much of her beliefs on her understanding of the nature of science, while Caroline and Jake sought to teach science as skills. All three mentioned some elements of inquiry as important to student learning. Yet, all three participants in this study engaged their students in didactic laboratory learning. The inconsistencies in their espoused beliefs and classroom actions led to tensions regarding the use of laboratories to teach science.
“Beginning teachers feel a special need to become a ‘member of the team’” (Eisenhart et al., 1988). Due to Jake and Lane’s participation in departmental planning meetings, the tension that emerged for each developed in part between their espoused beliefs and the influence of their colleagues. For Jake, the influence was on his understanding of what technical level students can and should do in laboratories. His intention to teach science as discovery was therefore, not realized. Causation can not be directly attributed in his case, to his colleagues’ influence because Jake’s prior experiences as a science learner and teacher also appeared to impact his classroom actions. However, Jake’s perceptions of his students and his classroom actions appear to be tightly linked to the influence that his colleagues had. Jake’s student ability frame resulted from the contrast between his espoused beliefs about the value of student-centered laboratories and his beliefs about what his students could and should do during laboratories. His frame was ultimately not based on what he knew about students abilities, but on what he believed students knew or were capable of. Ideally, reframing for Jake would take place based upon what he knows about how students learn—particularly, in this case, how his technical level students learn.

Lane’s experiences planning with her department also affected her beliefs. Her control frame developed from inconsistencies in her beliefs about the nature of science and the procedural control that guided her laboratories. During this study, Lane was unaware that her understanding of the nature of science was consistent with laboratories as traditional learning environments. Reframing for Lane would focus on development of knowledge of how students learn science and would additionally include a deeper understanding of the nature of science.

Caroline planned alone; therefore, the influence that her colleagues may or may not have had on her classroom actions is not clear. Caroline’s student reaction frame resulted from
conflicts between (a) her desire for her student to see laboratories as fun and student apathy and
(b) her desire to give her students more responsibility during laboratories and their
“conditioning” toward a lack of responsibility. Caroline faced her greatest tension from the
inconsistencies between her beliefs about laboratories as motivators and her students’ apathy
toward learning. Her students were not easily motivated and Caroline remained frustrated for
much of this study as she tried and tried to find ways to make science fun. She met continued
resistance to the notion that learning could be fun. In the end, her frame was based on how her
students reacted to her efforts during laboratories. She expected her students to follow directions
and be excited participants. Reframing for Caroline, like Jake and Lane, would take place as she
learns what her students know and how they learn and begins to focus on meeting them where
they are rather than where she expects them to be.

Caroline, Jake, and Lane struggled with the inconsistencies between their espoused
student-centered and teacher-centered classroom actions. The tensions that they experienced
however did little to perturbate their thinking about laboratories. In order to address their
tensions and reframe their beliefs about laboratories, Caroline, Jake, and Lane will need to
develop knowledge of how students come to understand science. In addition, they will have to
recognize their student prior knowledge and seek to teach them in ways that incorporate this.
During the study, Caroline, Jake, and Lane may not have had the time or any reason to analyze
their practice. Therefore, they may have fallen into the survival mode that most beginning
teachers face, become “part of the team”, and failed to realize that the beliefs that they espoused
were inconsistent with those that they enacted. After reading a draft of his chapter, Jake appeared
to realize this inconsistency. Whether or not he is willing and able to implement changes to his
teaching as his second year of teaching progress remains to be seen. Lane read her chapter and
stated that “it looked good”, but hopes to see the completed study so that she can reflect on her beliefs in an effort to improve her teaching. Caroline stated that my findings were consistent with her beliefs, but offered not other insight into whether or how the findings might have spurred her reflection on her beliefs.

The processes of planning, implementing, and assessing curriculum are daunting for many beginning teachers. In fact, Eisenhart et al. (1988) asserted that many teachers believe themselves to be inexpert in these areas. This phenomenon is seen in Jake’s willingness to do as his colleagues did, Caroline’s espoused beliefs that she did not yet know enough to engage her students in more student-centered ways, and in Lane’s willingness to do what her mentor teacher suggested. As stated previously, laboratory planning, implementation, and assessment prove especially difficult; therefore, Caroline, Jake, and Lane’s perceptions of their lack of expertise in these areas is not uncommon and reinforced their developing tension(s).

In light of these findings about Caroline, Jake, and Lane’s beliefs about the purpose and structure of laboratories, I examine the conclusions and implications that can be drawn from this study in the following chapter. I begin with general conclusions and then discuss what can be learned from their cases. Subsequently, I examine the implications that this study has for science teacher education and end with recommendations on directions for future research.
CHAPTER EIGHT

CONCLUSIONS AND IMPLICATIONS

Any learning which requires considerable changes in the learner’s existing ideas requires the learner to take a major responsibility for his/her own learning behavior. (Freyberg & Osborne, 1985)

Conclusions

Understanding laboratory teaching through Caroline, Jake, and Lane’s cases has the potential for revealing the complexities of beginning teachers’ espoused beliefs and classroom actions, the uniqueness of the laboratory as a science learning environment, and the significance of the first year of science teaching to the success of subsequent years. The beliefs about laboratories and how students learn that Caroline, Jake, and Lane held prior to preservice teaching and those that they began building during experiences in their science teacher education programs interacted in complex ways and resulted in inconsistencies between their explicit, espoused beliefs about laboratory teaching and their classroom actions. Those beliefs that were most closely aligned with how each participant learned best emerged as most salient. In all three cases, the participants in this study held primarily teacher-centered beliefs that focused on skill-building rather than the generation of knowledge. All three participants espoused to some degree, beliefs in the importance of thinking like a scientist and the nature of science; however, evidence of attempts at fostering conceptual understanding were absent.
While absent from Caroline, Jake, and Lane’s classrooms, the development of conceptual understanding by science students is one of the prominent goals of efforts to reform science education (AAAS, 1990; NRC, 1996; 2000); therefore, an understanding of the beliefs of teachers like Caroline, Jake, and Lane reveals how science teaching and learning are viewed by beginning teachers and offers insight into what steps must be taken in order to initiate reforms. Teachers must understand that teaching science as student-centered, and learning as student-generated, is fundamentally important to science learning (Anderson, 2002). All teachers can and should engage their students in investigating authentic questions generated from their own experiences (Anderson, 2002; Ausubel, 1968). Research indicates that these kinds of changes are possible and that many teachers can initiate them in their classrooms (Anderson, 2002).

However, teachers must be vigilant in their quest for such classrooms, because no one approach is ideal for all learners (Tobin, 1990), and teachers can expect to encounter barriers along the way.

Knowledge regarding who first-year science teachers are, what they know and believe about science and the purpose of laboratories are valuable additions to the research literature on teacher beliefs, knowledge, and learning, because a better understanding of first-year science teachers’ experiences yields information for preservice science teacher preparation programs, as well as of the challenges faced by all science teachers as they learn to teach in the unique environments defined by their classrooms. This knowledge also provides a starting point from which to understand and critique the effectiveness of science teacher education and induction-year support programs. It is my contention that these programs are infinitely valuable; however, without systemic change that acknowledges and addresses sustained support for beginning teachers from the university, state, local, and school levels that encourages laboratory teaching
based upon student-generated knowledge, their influence and that of the national science education reforms are doomed to fail (Gess-Newsome, 2003).

This multiple case study of three first-year secondary science teachers’ beliefs about laboratories provides additional insight into the intricacies that exist between teachers’ espoused beliefs and their classroom actions. In addition, this research allows a window into three teachers’ classroom during and interesting time in their professional development. The goal of this study was to examine how science teachers in their first-year of teaching define and use laboratories to teach science in light of science education reforms. I did not seek to generate prescriptive theory, but instead sought to contribute to an understanding of first-year science teachers beliefs about laboratories. Contributing to our understanding of science teachers’ beliefs about laboratories, this study adds to a growing body of research on teacher beliefs and teachers’ beliefs about laboratories. In addition, this study contributes to the body of research focused on science education reforms through science classrooms that encourage knowledge building by the students. By adding to the knowledge that science educators hold about beginning teachers’ beliefs and by informing research on the role of the laboratory in science classrooms, improvements in the way science teachers are prepared can continue to be made.

It is incumbent upon any study of teaching, whose purpose is improved education, to investigate the beliefs of science teachers as they learn to teach science. Hewson, Kerby, and Cook (1995) suggest that both beginning and experienced teachers’ beliefs about science teaching can result in ineffective teaching practices and may limit the development of professional knowledge. This study provides the insight needed to understand the importance of beliefs with regards to reforms. In the face of reform-based changes to the way science teaching and learning has occurred in schools, this research can also inform literature on the importance of
supporting beginning teachers as the strive to include student-centered pedagogies into their classrooms. As products of sixteen years of schooling, in which much of their learning was traditional, today’s beginning science teachers face significant barriers to success.

What Can be Learned from This Study?

Caroline, Jake and Lane did not believe that laboratories were useful for building student conceptual understanding. In fact, their conceptions of student-centered laboratories did not include evidence of knowledge of how students learn. Understanding this learning process is essential to the successful inclusion of laboratory work that encourages students to generate their knowledge based upon their own understandings and perceptions of science phenomena. This type of student-driven learning is described by Freyberg and Osborne (1985) based on a constructivist view of learning as put forth by Piaget. Under their definition, Freyberg and Osborne (1985) suggest that students learn through a series of steps that include actively selecting and attending to some, but not all sensory input, linking input to relevant memory stores, and retrieving and using input in the active construction of new knowledge. Students engaged in this “generative learning model” may accommodate new knowledge along side prior knowledge or may restructure and reinterpret ideas to include new learning. This kind of teaching is difficult due to the individualized nature of this process to each student and requires considerable skill and knowledge of teaching and learning to be successful, yet it remains the focus of efforts to reform science classrooms. The teacher’s role in these classrooms must be to organize and provide the learning experiences, but the knowledge generation must be accomplished by the learner. Both teacher preparation and induction-year programs are well-suited to effectively address these issues and guide young teachers in their development as fundamental to the success of this process.
In addition to Freyberg and Osborne’s (1985) suggestions for student-generated learning, the National Research Council (2000) has outlined six pertinent research findings on how students learn that support the development of generative learning classrooms:

1) Understanding science is more than knowing facts;
2) Students build new knowledge and understanding on what they already know and believe;
3) Students formulate new knowledge by modifying and refining their current concepts and by adding new concepts to what they already know;
4) Learning is mediated by the social environment in which learners interact with others;
5) Effective learning requires that students take control of their own learning;
6) The ability to apply knowledge to novel situations, that is, transfer of learning, is affected by the degree to which student learn with understanding. (pp. 116-119)

By developing an understanding of how students learn, Caroline, Jake, and Lane could begin to reframe the tensions that emerged during this study. In fact, this is a crucial first step to enacting reform-based changes in their classrooms. Caroline, Jake, and Lane held naïve conceptions of what it means to be student-centered. They encountered barriers to their beliefs about student-centered classrooms in the form of tensions that arose due to inconsistencies in their beliefs. Caroline’s student reaction frame, Jake’s student ability frame, and Lane’s control frame emerged as they learned to teach science based upon their beliefs. Reframing for each must start with acknowledgement that there are inconsistencies in their beliefs and that they engaged in laboratories merely as hands-on, rather than minds-on activities. Their experiences suggest the
critical need to address both preservice teacher education and induction-year support because as beginning teachers learn to teach, they do so alone with little support from their colleagues or school systems and they tend to revert to teaching the way that they were most comfortable learning. In combination, this lack of support and tendency to seek what they know as learners, beginning teachers engage in teacher-centered lessons despite university and reform-based encouragement to implement student-centered pedagogies.

For beginning teachers to be successful at the implementation of student-centered lessons in which conceptual understanding is built through engagement in laboratories, significant changes must take place at all levels of teacher preparation and support. First, beginning teachers must receive exceptional preparation for their classrooms in terms of content, pedagogy, theory, and the modeling of effective teaching practices. Science education programs must also remain reactive to the needs of beginning teachers as they prepare preservice teachers. In addition to teacher preparation programs that develop professional beginning teachers, other teachers, parents, and policy makers must be convinced of the importance of student understanding to effective learning in the science classroom.

Implications for Science Teacher Education

Tamir (1989) called teaching in the laboratory “a persistent and recurring problem in the practice of science education.” However, few teacher education programs offer instruction on how to teach in the laboratory, and since teachers tend to teach in the way that they learn best (Czerniak & Lumpe, 1996), teachers who have not experienced student-centered learning that focuses on building conceptual understanding themselves, will be unprepared to teach that way (Schwab, 2000). Tamir suggested that “…the effectiveness of learning in the laboratory can be achieved only through substantial improvement in teacher preparation” (1989, p. 60). It is clear
from this study that teacher preparation must take a serious look at the beliefs of preservice teachers in order to affect change. Teachers’ beliefs are often not examined in preservice teacher programs (Czerniak & Schriver, 1994; Haney & McArthur, 2002). And without careful examination of teachers’ developing beliefs, Haney and McArthur (2002) believe that it is possible that we are setting our students up for frustration and failure. This study sought to give voice to first-year teachers’ beliefs and describe their inconsistencies, but a greater effort toward examining teachers’ beliefs must also take place in teacher education programs. Contributing to the research that focuses on secondary science teachers’ beliefs about laboratories, this study will have implications for preservice science teacher preparation programs and inservice teacher support programs by informing teachers, administrators, policy makers, and science educators about the importance of recognizing, exploring, and respecting the beliefs of all teachers.

Implications for science teacher education from this study include:

- Science teacher education programs can emphasize the development of a mature understanding of how students learn.
- Science teacher education and professional development programs can focus on improving the epistemological knowledge of teachers so that they learn to make connections between their knowledge and what their students know.
- Science teacher education programs can use information on first-year secondary science teachers’ beliefs to address the beliefs that preservice teachers hold, in an effort to bring them into concert with nation reforms and help them sustain them as they begin teaching.
- Science teacher education programs can begin to model for preservice teachers, laboratory lessons that mirror suggestions made in the national reforms, and provide for them opportunities to observe and work with teachers doing the same.
Ideally, site-based science teacher education programs can begin earlier in preservice teaching in an effort to begin addressing these issues when first engaging in pedagogical discussions.

The complexity of Caroline, Jake, and Lane’s beliefs suggest that the above implications are not magic bullets for science teacher education. Core beliefs that teachers bring with them to teacher education programs complicate the incorporation of newer, reform-based beliefs. Sixteen years as students in primarily teacher-centered classrooms is not simply undone or “fixed” by one year or a single semester in a methods course; however, identifying and challenging science teachers’ beliefs from the beginning of and throughout their teacher education programs, as well as during their first three years teaching can begin to affect reform-based change.

In order to implement student-centered science teaching into secondary science classrooms, I recommend a laboratory-based methods course for science teacher education programs that focuses on modeling pedagogies that encourage students to generate knowledge. This course would incorporate classroom observations of laboratories in schools, laboratories at the university, readings on the value of practical work (e.g., *Which Way Now*?), and discussions about laboratory teaching with extensive integration of each teachers’ beliefs about laboratories. It would be an opportunity to examine planning, authentic assessment, and classroom management considerations for science lessons. Methods courses can powerfully impact preservice teachers’ beliefs (Abell & Bryan, 1997), but more need to be done to address beliefs about laboratory work and reinforce more desirable beliefs (based on the reforms) during preservice and induction-year teaching. By focusing this methods course on teachers’ beliefs around the implementation of student-centered pedagogies, preservice science teacher education programs could significantly impact how and why laboratories are taught.
In addition to a focus on teacher beliefs and on modeling effective practice in the laboratory, I recommend that all science teacher education programs engage preservice teachers in science classrooms from the beginning of their programs. Those methods courses that are currently being taught at schools provide rich learning environments for preservice teachers and should extend beyond a single semester. Science course work and education classes should be taught with students, mentors, and supervisors present at all levels. This support while learning to teach for student understanding is essential to the success of these teachers and their students.

Tobin (1990) suggested that substantive changes in science classrooms are unlikely unless the way teachers and students conceptualize their roles changes. He states that “most teachers do not understand the role of laboratory activities as a means of allowing student to solve problems and thereby construct knowledge of science” (Tobin, 1990, p. 415). In addition, Thomas, Pedersen, and Finson (2001) suggest that opportunities to critically examine beliefs and knowledge that prospective teachers bring with them as well as those they develop or reinforce during teacher preparation programs.

Implications for Induction Teacher Support

As evidenced in this study, the school culture can have devastating effects on the success or failure of beginning teachers. For Jake and Lane and to a lesser extent, Caroline, the influence of colleagues’ beliefs about what should and can be accomplished in science classrooms significantly impacted what they chose to do during their lessons and often, their beliefs about the use of laboratories to teach science. In order for beginning teachers to remain as unaffected as possible when confronted with school and departmental norms and the pervasive beliefs of their colleagues, school systems have a responsibility to confront the integration of new teachers and new teaching ideas into their school systems directly. Stakeholders in the success of
beginning teachers must be convinced of the importance of laboratories as means of generating knowledge in science classrooms. In fact, they must be certain that this type of teaching and learning is more important than learning facts and vocabulary (Anderson, 2002). Otherwise, beginning teachers face overwhelming pressure to abandon lessons aimed at student understanding for lessons that produce high test scores. Anderson’s (2002) recommendation suggests that teachers who teach based on factual recall and memorization, especially in systems that utilize high-stakes testing, cling to facts and vocabulary because they are judged based upon their students’ performance on evaluations. This task must be addressed systemically and administrators must take an active role in supporting teachers in their efforts (Lumpe et al., 2000) if a shift is to occur from reliance on recall to constructivist learning.

Once convinced of the importance of this kind of teaching, which is no small feat, school systems must provide constant support for their beginning teachers in the form of mentoring, professional development, and system-wide, new teacher community building. Implications for induction-year teacher support from this study include:

- Stakeholders in the success of induction-year teachers must support the efforts of beginning teachers as they struggle with their identities as teachers and learners and as they incorporate lessons that may not be supported by high-stakes, multiple-choice testing, but are supported by efforts to improve science education.

- Those who support beginning science teachers should provide structure that encourages and allows the further development and nurturing of beliefs that are in line with national reform efforts (e.g. mentoring programs).

- New science teachers must be mentored by knowledgeable, experienced science teachers who are either using lessons aimed at enhancing student understanding through
laboratories or who are actively pursuing the incorporation of that type of teaching into their classrooms.

- Professional development programs can emphasize the development of a mature understanding of how students learn.
- Communities of beginning teachers must be established so that weekly or bi-monthly meetings that are focused on the development of student-generated knowledge as well as the professional needs of beginning teachers.
- Ideally, universities should remain in contact with their teaching graduates during their first year of teaching to establish support for new teaching techniques that may not yet be accepted in the teachers’ new schools.

The systemic changes that must take place in schools and systems so deeply entrenched in the way they have always conducted schooling for this type of radical shift toward student understanding to occur are wide-ranging. It is clearly not just the beliefs of the first-year teachers that are important in such a significant shift. However, identifying, honoring, and addressing the beliefs of first-year teachers is fundamental to this move science student capable of truly understanding science and competing in a global communities.

Caroline, Jake, and Lane’s beliefs identify how individual their needs as beginning teachers were. The pressures of learning to teach were apparent in their espoused beliefs and classroom actions. Individualized, sustained support from their school systems that is reactive to their needs as teachers and learners can initiate a shift toward less teacher-centered classrooms for these three teachers. Fairfield County has an opportunity and an enormous responsibility to shape the future of science education in their system by working with their beginning teachers. Through sustained efforts, their science teachers can make a significant impact on student
learning in their county and they can act as models for such support. These changes are not easily implemented, but their importance to the future of science education is crucial.

**Directions for Future Research**

The complexity of espoused beliefs and classroom actions, and changes in each requires the adoption of different teaching-related knowledge, thoughts, and practices and a rethinking of teacher education and induction-year experiences. More research needs to be done on teaching and learning in the laboratory. The use of laboratory teaching over the past century and its importance in reform initiatives and science education literature are in sharp contrast to research on the failure of laboratories to result in meaningful learning. There is a mismatch between what theory and research says about the laboratory and there is a mismatch between what both says should take place for meaningful science learning to occur and what is actually taking place. These mismatches can be addressed through research on teacher beliefs that begins when teachers enter pre-service science education programs. By giving voice to teachers’ beliefs early and often, and by making them the focus of science teacher education programs, progress can be made first, toward bringing teachers’ beliefs into concert with reform initiatives and then, bringing more meaningful learning into the laboratory.

Significant change in classroom practice is only foreseeable if teachers’ beliefs are taken seriously by all stakeholders in the success of science education (Hodson, 1993a). “Unless extended efforts are made to nurture new beliefs and make them core, they are likely to be extinguished or never enacted” (Gess-Newsome, 2003, p. 30). This research begins to question the sustainability of influences from preservice education when those influences conflict with deeply held beliefs, like Caroline’s, Jake’s, and Lane’s, about laboratories as verification tools. First-year teachers need the support of the total education context in order to support the
influences of their methods programs. “Beginning science teachers need on-going support in areas that are of concern to all teachers, as well as areas that are unique to science teachers…need support programs that address their beliefs and practices, and help them build their knowledge about science and teaching science” (Luft & Patterson, 2002, p. 270) Therefore, long-term “induction programs for beginning science teachers are increasingly important” (Luft & Patterson, 2002, p. 267). These programs must attend to beginning science teachers’ beliefs, practices and knowledge (Luft & Patterson, 271).
REFERENCES


Gudmundsdóttir, S. (2001). Narrative research on school practice. In V. Richardson (Ed.),


## Appendix A

### CHART OF DATA COLLECTED

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<th>Lane 08-04-03</th>
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<td>12-9 &amp; 10-03</td>
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<th>~ e-mail of classes taken and extra curricular activities</th>
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<td>Observations – 1, 3, 7-10</td>
<td>Observations – 1-10 and Microscope lab</td>
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Questions for Interview One

1. Tell me why you chose to become a teacher.

2. Think of a teacher that you had that stands out for you and tell me about him/her.

3. Tell me about an experience teaching that stands out for you.

4. Tell me about interactions that you’ve had as a teacher.

5. Tell me about your best day teaching and tell me about it.

6. Think of a lab that stands out for you and tell me about it.

7. Tell me about how you determine if a lab is effective.

8. Tell me about a lab that you felt wasn’t effective.

9. Tell me about the purposes of labs in your teaching.

Questions for Interview Two

1. Tell me about your first few weeks teaching laboratories.

2. What have you learned about labs?
   a. What has worked?
   b. What would you change/do differently next time?

3. When you plan for a lab, what kinds of things do you have to think about?

4. When you assess a lab, how can you tell if it was successful (grades, student response, etc.)?
Appendix C

CAROLINE’S LAW OF INERTIA LABORATORY

For this lab we will be investigating Newton’s 1st Law, the Law of Inertia.

Materials:
1 toy car     1 ruler
1 section of car track   1 stopwatch
1 piece of graph paper   A small amount of clay
1 pencil     Several small strips of tape

Procedure:
1. Place the graph paper on the table and tape it in position.
2. Tape the pencil to the table along the edge of the graph paper.
3. Measure 20 cm from the taped pencil and place another piece of tape on the table at that position.
4. Create a “person” from the clay.
5. Set the clay person on the top/hood of the toy car. You just want your person to rest on the care and not to be physically stuck to the car.
6. Hold the section of the car track so that one end rests on the tape that is 20 cm from the pencil.
7. Place the car with its clay passenger at the end of the track and then release the car.
8. Use the stopwatch to time how quickly the car travels the 20 cm on the table and record your data in the table provided below.
9. With a pencil, mark the clay person’s landing spot on the graph paper than measure the distance between this mark and the taped pencil. Record this number in the table provided.
10. Repeat the experiment for a total of 5 trial runs. The only variable you will change for each trial is the angle between the table and the track. The angle should start small (almost horizontal with the table) and gradually increase with each trial.

Data & Calculations:

<table>
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<tr>
<th>Trial</th>
<th>Travel Time(s)</th>
<th>Distance Traveled (cm)</th>
<th>Velocity of the Car (cm/s)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trial</th>
<th>Distance Traveled by Clay Person (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
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<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>
Use your data and calculations to create a graph of the car’s velocity vs. the distance traveled by the clay person. Use the grid provided.

**Analysis:**
1. What does the slope of your graph tell you about the relationship between the velocity of the car and the distance the clay person traveled?

2. Explain how this experiment demonstrates Newton’s 1st Law.

3. Compare your results with those from other groups. What could have caused the differences in your results?

4. Why is wearing the seatbelt in your car important? Explain your answer in terms of Newton’s 1st Law.
Appendix D

JAKE’S CONSERVATION OF MASS LABORATORY

Purpose: Provide support for the Law of Conservation of Mass

Hypothesis: If my experiment supports the law of conservation of mass, then the mass before the reaction will equal the mass after the reaction.

Materials: 1 fizzy antacid tablet, broken in half
Water
Small flask
Balloon
Balance

Procedure: (Work through the development of the procedure with your class as they write this lab on their paper.)

Steps you could include:
1. Put half of the antacid tablet in the balloon.
2. Fill the flask ¼ full of water.
3. Carefully cover the flask with the balloon. (DO NOT LET THE TABLET FALL INTO THE WATER.)
4. Measure and record the mass of the balloon, flask, and water.
5. Drop the tablet into the water.
6. After the reaction is complete, mass the flask, with contents and the balloon still attached.
7. Repeat steps 1-6.

Data Table: (Help students determine what data they need to collect.)

Analysis: Average your data.
Calculate you percent error using this formula:

\[
\frac{\text{Mass before reaction} - \text{Mass after reaction}}{\text{Mass before reaction}} \times 100 = \% \text{ error}
\]

Conclusion: Write a concluding paragraph in which you
a. State the law of conservation of mass.
b. Provide evidence to support (or not support) the law of conservation of mass.
c. Discuss possible sources of error, if necessary.
Appendix E

LANE’S LIVER ENZYMES IN ACTION LABORATORY

Name__________________________ Date____________ Period_________ Score____________

Purpose: To see how liver enzymes work to break down hydrogen peroxide into water and oxygen.

Introduction: Much of life is a series of ongoing chemical reactions. The interactions between the chemicals we each and drink sustain life. Most of these reactions would not take place without the help of catalysts for enzymes. Catalysts or enzymes generally speed up the rate of a reaction by providing surfaces for the reactants to come together. In this investigation, you will use the enzymes catalase which is found in liver. This enzyme is responsible for the rapid breakdown of hydrogen peroxide to water and oxygen.

Catalase

Equation of Reaction: \( 2H_2O_2 (aq) \rightarrow 2H_2O (l) + O_2 (g) \)

Materials: (For a 7 Group lab)

- 7 Test Tube Racks
- 7 Test Tubes per rack
- 7g of MnO₂
- 7 Test Tubes per rack
- 7 wooden splints
- 7g of MnO₂
- 1 small bottle of H₂O₂ (3%)
- 1 Water bath (500 ml beaker)
- 1 ice bath (500 ml beaker)
- ¼ pound of beef liver
- 1 M HCl (used in liver preparation)
- 7 Forceps
- 1 M NaOH (used in liver preparation)
- 7 small graduated cylinders

CAUTION: WEAR YOUR GOGGLES THE ENTIRE PERIOD!!! EXERCISE EXTRA CAUTION WHEN HANDLING THE LIVER WITH HCl AND NaOH. IT WILL BURN YOUR SKIN!!!

Procedure:

Part A

1. Add 2 ml of hydrogen peroxide (H₂O₂) to a test tube. Next add a small amount of sand (approximately 5 ml). Record the intensity of any foaming action on your chart. Use a scale of 0 to 5, making 5 the most intense.
2. Add 2 ml of H₂O₂ to a clean test tube. Add one splint end full of MnO₂. SHAKE GENTLY. When the mixture foams, place a glowing splint in the test tube, but NOT THE FOAM. Observe this catalyst in action.

Part B:

1. Regular Liver: Place one chunk of liver in test tube 1 and add 2 ml of H₂O₂. Record the intensity of the foam in your chart using the 1-5 scale.
2. Ground Liver: Scoop the ground liver, as large as the previous chunk, into test tube 2. Add 2 ml of H₂O₂ and record the intensity of foam on your chart.
3. Hot Liver: Place the boiled liver into a test tube and add 2 ml of H₂O₂. Record the intensity of the foam in your chart.

4. Cold Liver: Place the ice cold liver into a test tube and add 2 ml of H₂O₂. Record the intensity of the foam in your chart.

5. HCl Liver: Place the liver soaking in HCL into a test tube. Add 2 ml H₂O₂. Record the intensity of the foam in your chart.

6. NaOH Liver: Place the liver soaking in HCl into a test tube. Add 2 ml H₂O₂. Record the intensity of the foam in your chart.

Data Table:

<table>
<thead>
<tr>
<th>Substance Tested</th>
<th>Amount</th>
<th>Reaction Intensity on 0-5 Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Include Condition</td>
<td>H₂O₂</td>
<td>(0=no foam and 5=much foam)</td>
</tr>
<tr>
<td>1. Sand</td>
<td>2 ml</td>
<td></td>
</tr>
<tr>
<td>2. Regular Liver</td>
<td>2 ml</td>
<td></td>
</tr>
<tr>
<td>3. Ground Liver</td>
<td>2 ml</td>
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</tr>
<tr>
<td>4. Boiled Liver</td>
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<tr>
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<td></td>
</tr>
<tr>
<td>6. HCl Soaked</td>
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<td></td>
</tr>
<tr>
<td>7. NaOH Soaked</td>
<td>2 ml</td>
<td></td>
</tr>
</tbody>
</table>

Questions:

1. What happened when you placed the glowing splint in the test tube with H₂O₂?

Explain what reaction the wooden splint results show.

2. What general statement can you say about each factor’s effect on the rate of the reaction?

increase temperature –

decrease temperature –

increase in surface area (ground) –

acid –

base –

3. Draw a Likert scale placing each liver treatment in the appropriate place along the scale.

4. Explain the purpose of using just sand with the H₂O₂.

5. What type of reaction is the equation that explains the reaction performed in this experiment?
VITA

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November 2004

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B.A. Biology

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Professional Experience

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Teaching Experience and Assistantships

Teacher, Department of Science Education, Enhancing Middle and Elementary Mathematics and Science (Project EM & EMS)
Enrollment – 22
Summer 2003

Teaching Assistant, Department of Science Education, Science Teaching Methods in the Middle Grades (ESCI 4440)
Enrollment – 25
Fall 2001

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Enrollment – 20
Summer 2001
Teaching Assistant, Department of Science Education, Science for Early Childhood Education (ESCI 4420)
Enrollment – 25
Spring 2001

Project Wild Facilitator, Project Wild
1999-present

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Teacher, Biology, Honors Biology, and Human Anatomy and Physiology
1998-2000
1994-1996

Non-teaching Experience and Assistantships
Graduate Assistant, Qualitative Interest Group Conference
2003-2004

Graduate Assistant, Qualitative Inquiry Program
2003-2004

Graduate Assistant, Learning and Performance Support Laboratory, Eishenhower – Scientific Working of Everyday Things
2002-2003

Student Teacher Supervisor, University of Georgia, Science and Social Science Education
2001-2003

Graduate Assistant, Learning and Performance Support Laboratory, Virtual El Niño
2001-2002

Program Evaluator, Emory Division of Educational Studies External Evaluation Report: Ph.D. Program in Educational Studies
2001-2002

Publications


Presentations at Professional Meetings


### Professional Organizations

- Association for the Education of Teachers in Science
- Georgia Science Teacher’s Association
- Kappa Delta Pi
- National Association of Biology Teachers
- National Association of Research in Science Teaching
- National Science Teacher’s Association
- Phi Lambda Theta

### Awards and Honors

- Phi Delta Kappa National Honor Society: 2003-present
- Kappa Delta Epsilon – Outstanding Graduate Assistant: 2002
- Georgia Science Teacher’s Association Executive Board: 2002-2004
- Dell Jones Memorial Scholarship: 2002-2003
- Kappa Delta Pi National Honor Society: 2001-present
  - 2nd vice-president: 2001-2002
  - 1st vice-president: 2002-2003
- Phi Lambda Theta National Honor Society: 1998-present
- Passed Master’s Degree Comprehensive Exams with honors: 1998

### Service Activities

- Proposal Reviewer for the 2004 Higher Education Portion of the No Child Left Behind Act
- Proposal Reviewer for 2004 and 2005 Qualitative Interest Group (QUIG) Conference
- Proposal Reviewer for 2002 National Association for Research in Science Teaching Conference, Teaching Strand
- Department of Science Education, Revision of Secondary Program: 2000-2001
- Department of Science Education, Secondary Committee Member: 2000-2001
- Department of Science Education, Master’s Committee Member: 2000-2001
- Reviewer for National Board of Professional Teaching Standards: 2000