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The Cultural Studies of Science Education

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THE CULTURAL STUDIES OF SCIENCE EDUCATION

by

KAREN D. CHASSEREAU

(Under the direction of Lina B. Soares)

ABSTRACT

In an age of accountability, the demands and constraints placed on science teachers seem insurmountable. Teachers are challenged to provide students with authentic scientific experiences, yet the need to prepare students for high-stakes tests remains. The problem of attrition and job stress in the field of science teaching is growing. As pressures rise, it becomes necessary to understand what the culture of science education is like from the perspective of the science teacher. This study sought to define the culture of science education and determine how this culture informs teacher practice in the secondary science classroom. This qualitative case study was conducted within the context of a small, rural high school with four science teachers. Data was collected through a number of procedures that included participant observation, field notes, interviews, informal conversations, focus group interviews, audio recordings, and artifacts from the school. Data analysis was conducted using inductive coding processes and grounded theory. This study found that the culture of science education was defined by the constant collaborative nature of the community of practice, the formation and negotiation of teacher identity, and policies mandated by both state and local school administration. These aspects of the culture informed teacher practice through the method of instruction used in the classroom and the depth of inquiry allowed for laboratory work.

INDEX WORDS: Science Education, Cultural Studies, Teacher Practice, Pedagogy, Culture of Science, Communities of Practice, Sociocultural Perspectives

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DEDICATION

This dissertation is dedicated to those who hold my heart, my family.

First of all, I dedicate this dissertation to my husband and daughter. The support you have given me throughout this process is immeasurable. Doug and Allison, I love you both with all my heart!

Secondly, I dedicate this dissertation to my mama and daddy. Mama has shown me how strength, perseverance, and faith in God can move mountains. Daddy has taught me that, in all things, family is the most important. He has shown me that determination and love of family can pull you through the most challenging of battles, especially battles of the mind. Thank you for being the most amazing parents anyone could ask for.

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For Dr. John Weaver, who forever had a new book to add to my reading list, I am grateful to you for giving me a new lens to view the world of science.

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CHAPTER ONE: INTRODUCTION

In an era of standardization, the science curriculum is authorized by state and local government and suggestions for implementation accompany them (*National Science Education Standards*, 1996). Yet, every science teacher should have as his/her goal to provide students with authentic scientific experiences that serve to prepare them for challenges that they will face in the future. In fact, evaluations of teaching practice conclude that both inquiry and direct instruction are beneficial to the teaching of science and helping students to form problem-solving skills, in spite of the fact there are a multitude of factors that influence pedagogy used in science education (Cobern, Schuster, & Adams, 2010; Heppner, Kouttab, & Croasdale, 2006; Robertson, 2006; Sanger, 2007). While research shows that teachers are often bound by guidelines of what to teach, they have a great deal of autonomy in how they teach (Weiss, Pasley, Smith, Banlower, & Heck, 2003). This means that teachers have a choice of which pedagogical tools and strategies that they believe will best suit the learning needs of students in their classrooms. Therefore, the content addressed and the pedagogy applied to the classroom is ultimately in the hands of the teacher.

There are many factors that determine "what content is taught, how it is taught, and the materials selected to engage students with the content" (Weiss, Pasley, Smith, Banlower, & Heck, 2003, p. 73). When asked to identify factors that influenced their choice of content and pedagogy in science and mathematics for lessons in grades K-12, teachers in one study identified state and district curriculum standards/frameworks as the leading factor for choosing content. For the same group of teachers, the factor that most impacted pedagogical strategies was the teacher's own knowledge, beliefs, and experience (Weiss, Pasley, Smith, Banlower, & Heck). Teacher education programs and professional development provide teachers with pedagogical tools for addressing the needs of a diverse student population and provide a differentiated approach to teaching content. Global and community issues influence the way that we approach the sciences and dictate which concepts are considered important for students to learn. Curriculum mandates established by state and local school boards lay the framework for what teachers use in their classrooms (NRC, 1996).

How teachers approach these curricula and how they are influenced by other factors is reflected in their teaching practice. The literature is saturated with analyses of pedagogical strategies for the teaching of science: direct instruction (Cobern, Schuster, & Adams, 2010; Dean & Kuhn, 2007; Klahr & Nigam, 2004), inquiry (Anderson, 2002; Banerjee, 2010; Burton & Frazier, 2012; Crawford, 2007; Mistler-Jackson & Songer, 2000; Sanger, 2007), discovery learning (Alfieri, Brooks, Aldrich & Tenenbaum, 2011; Trowbridge & Bybee, 1996). However, what peaks my curiosity is not whether one form of instruction is better than another. Instead, I am interested in how the culture of science education influences a teacher's decisions regarding pedagogy and approach to teaching science. Defining the culture of science education requires an understanding of the larger culture to which it belongs. The culture of science is the umbrella under which the culture of science education falls. This implies a hierarchy in which the overarching culture of science informs certain values and expectations science teachers are exposed to prior to and during their careers in the classroom. Science teachers, in turn, are responsible for disseminating, to their students, both the practices of scientists and the science content knowledge representative of the culture of science. How this culture, specifically the culture of science education, informs the way that science teachers relay scientific knowledge to their students is the focus of this dissertation.

The Culture of Science and Science Education

In this study, the history and sociology of science was used to better understand the culture of science education. Participation in science culture may occur at varying levels of interest and immersion for different science teachers, but each has experience with the culture and the knowledge that it produces. The cultural studies of science provide a framework for understanding the culture of science education in two ways. First of all, the social situations and interactions that occur within the culture of science provide evidence that the culture of science is comprised of many different communities of practice. This study used communities of practice (Lave & Wenger, 1991) to explain the sociocultural interactions that occur among science teachers (Vygotsky, 1978; Wertsch, 1985, 1991) and their colleagues in the culture of science education. Therefore, examples of communities of practice within the culture of science provided models that were used as reference for this study. The second consideration was that science teachers learn a portion of their practice through the process of situated learning (Gee, 2001) within the culture of science. While on the path to becoming a science teacher, individuals interact with members of the science community. At various levels of participation they learn from their science professors and others in the field; they learn from and assist in the science laboratory, and many science teachers become scientists themselves, working in various science disciplines before entering the teaching profession. Even as a practicing science teacher, involvement in the culture of science may continue through participation in a variety of communities of practice, both through professional development and other work related interests or through hobbies.

Understanding the history and culture of science was essential to gaining a meaningful interpretation of the culture of science education. Throughout the cultural studies of science, sociologist, anthropologists, historians, and philosophers of science reveal its culture using an intricate study of scientists' behaviors, associations, and instruments in an effort to uncover the nature of scientific discovery and knowledge acquisition. Studies that focus on the culture of science (Galison, 1987, 1997; Galison & Stump, 1996; Latour 1987; Latour & Woolgar, 1986 ; Traweek, 1988) reveal much more than accepted concepts, theories, and current practices. These studies open the doors to the laboratory to provide access to the scientists' world, not just to the results and accepted explanations for scientific phenomena that often appear in science textbooks, but also to scientists' very existence, their fears, failures, and triumphs. Probing deeper into the world of science, and more specifically, the scientific laboratory, tells the story of a more fluid science that has changed and evolved throughout, and along side, human history. The researcher used literature in the culture of science as a pathway to understanding the obstacles and milestones that paved the way to current and future scientific knowledge. In this dissertation, the history and philosophy of science was used to provide a new perspective on how science teachers view the culture of science and enable us to take a deeper look at science education.

Science teachers receive little exposure to the cultural studies of science, and therefore, have little knowledge of its implications for the field of science education (Weaver, Morris, & Applebaum, 2001). Rudolph (2003) contends that, in classroom situations, the definition of science is given as beneficial to modern society, but at the same time, "essentially free from social or political bias" (p. 65). This imparts a false image of science as sterile and free from human influence. Through a study of the scientific culture, this thin veil of objectivity is removed to reveal the political and social nature of science that is seldom incorporated into science curricula. The associations between science and society throughout history are often unfamiliar to science teachers because this type of realization about the world of science does not come from a textbook. In Grinnell's *Science and Society* (2007), Stephen Jay Gould offered a definition of science as "a fruitful mode of inquiry, not a list of enticing conclusions" (p. 22). Gould establishes that the conclusions that appear in the curriculum and in science textbooks are not the essence of science, but instead, are the consequences of scientific discovery. The science curriculum plays an integral role in how society defines science yet its influence is largely overlooked by those seeking to understand the culture of science (Shapin, 1995).

The cultural studies of science informed this inquiry into the culture of science education by giving insight into the culture of science and providing a myriad of exemplars for ethnographic study. Examples include Peter Galison's studies of theoretical and experimental physicists in the field of particle physics, Sharon Traweeks study in the culture of physics in the United States and Japan, and Bruno Latour's study of laboratory culture, among others. Each account provided a rich and detailed account of the lives of scientists in the field and/or laboratory that demonstrate evidence of the social aspects of science. These accounts enabled a better understanding of issues and constraints that impact the scientific world throughout history and help make connections between science and the changes in science education and curriculum. Social interactions within the different fields of science and within society as a whole help determine the issues that are considered important for scientific study, and also influence decisions about which research is considered worthy of financial backing by either government or corporate funding. This study also drew from examples of ethnographic studies conducted in the history and philosophy of science (Traweek, 1988; Latour, 1999; Latour & Woolgar, 1986; Galison, 1997). The ethnographies and detailed historical accounts of the culture of science informed this approach to understanding the culture of science education.

Science teaching, much like scientific practice, cannot be isolated from its social and political context. Rudolph (2003) argues for more open discussion concerning the social and political concerns in science education. There is a need to understand more about the culture of the science classroom and groups associated with teaching science. Much of the research involving science education through the lens of scientific culture focuses on development of more authentic science experiences for students and early initiation into scientific discourse (Bricker & Bell, 2008; Cunningham & Helms, 1998; McGinn & Roth, 1999; Rudolph, 2005) or using such sociocultural perspectives to address a social or ecological concern (Carter, 2007). One study that focused on support for teachers was geared towards achieving successful school reform (Davis, 2002). Although increasingly more research is done to incorporate cultural studies of science, particularly science studies in science education research, the “blind spot” is yet to be filled (Duschl, et al, 2006). More research is needed to better understand the concerns of science teachers, not solely to aid in curriculum reform efforts, but more importantly to appreciate the struggles and better understand the stresses that teachers encounter in the day-to-day practice of science teaching. This study was inspired by that need.

Communities of Practice

The concept of community of practice was used as an analytical tool to make defining the culture of science education a more manageable task. Components of social theory of learning, including community, practice, identity, and meaning, are integrated into the concept of community of practice as a starting point for understanding culture (Wenger, 1998). The sociocultural perspectives within the culture of science education can be better understood using the concept of a community of practice. Whether formal or informal, communities of practice permeate our daily lives. Wenger (1998) suggests that we are part of any number of communities of practice with varying levels of membership and participation. These include groups of people that we interact with in both our personal and professional lives. This suggests that the communities formed within both the culture of science and the culture of science education are likely examples of communities of practice, and ultimately, these cultures can be better understood by describing the social interactions that occur within them.

Although "most communities of practice do not have a name and do not issue membership cards" (Wenger, 1998, p. 7), they serve as an integral part of our learning dynamic in both professional and personal venues. For example, a science teacher is a member of a community of practice that includes fellow science teachers. This same community might involve colleagues who teach mathematics, history or language arts, even school and system administrators and students. This same science teacher could also be a member of many communities of practice that occur outside of the school setting. These could relate to his/her hobbies, interests, or other science and non-science affiliations. Understanding how communities of practice are formed is a vital component to this interpretation of the culture of science education. A science teacher could be a member of any number of communities of practice, both presently and prior to becoming a teacher. Through social interactions with colleagues and counterparts, individuals are able to negotiate meaning and learn the dynamics of the community. When entering the profession, the science teacher is charged with developing essential skills and knowledge necessary to be an accepted member of the social group. Through interactions with experienced members of the community of practice, those who Lave and Wenger (1991) refer to as "old-timers," the science teacher undergoes a sociocultural transformation within the context of practice. The newcomer learns what is necessary to achieve full participation within the community.

Members and potential members of a community of practice develop and refine their role in the community through legitimate peripheral participation as part of the process of situated learning (Lave & Wenger, 1991; Wenger 1998). Learning occurs within the context of social practice. Vygotsky (1978) suggests that becoming and being part of a community of practice contributes to the formation of identity and leads to discourse within the community that helps to define knowledge. Gee (2001) suggest that the formation of an individual's identity is impacted by many "sociocultural forces" (p. 100). A person's identity may change from one situation to the next. For a science teacher, these factors may be derived from numerous social situations including the cultures of science, education, or his/her personal involvements outside of the fields typically associated with science teaching. Lave and Wenger (1991) establish that development of one's identity is essential to becoming a contributing member of a community of practice.

Statement of Problem

The problem of attrition and job stress in the field of science teaching has been identified. High levels of teacher stress result in increased frustration and anxiety leading to increased absenteeism and decreases in overall teacher performance (Harris, Halpin, & Halpin, 1985). Intense stress can lead to teachers leaving the school or leaving the field of education entirely. The level of stress a teacher experiences is dependent upon different teaching situations. According to a study of science teacher stress levels, teachers of science are prone to face more pressure than non-science teachers (Halim, Samsudin, Meerah, & Osman, 2006). Borman and Dowling (2008) suggest that teachers who have specialized degrees in science or mathematics have higher attrition than those in other subject areas. They further propose that it is the more experienced and highly talented teachers who tend to be lost at a higher frequency than others.

Jepson and Forrest (2006) cite additional stressors, such as an extensive workload, initiative overload, a target-driven culture, and student behavior and discipline as reasons for teacher attrition. Teacher stress often leads to burnout and stress-related illness, and frequently results in teachers seeking early retirement (Borman & Dowling, 2008; Brown, Ralph, & Brember, 2002; Halim, Samsudin, Meerah, & Osman, 2006; Harris, Halpin & Halpin, 1985; Jepson & Forrest, 2006). Evers, Brouwers, & Tomic (2002) note that teacher burnout has gained national attention in the US. In their study of teachers in the Netherlands, it was suggested that teachers involved in top-down planning strategies often expressed resistance or indifference to the initiative. Teachers who maintained a more negative attitude towards the reform initiative had a greater tendency to "suffer from depersonalization and emotional exhaustion" (p. 234).

Reform and constant demands for change have been noted among the sources of teacher stress (Brown, Ralph, & Brember, 2002). Changes in science curricula that could impact the demands on science teachers occur at the district, state, and national levels. Current initiatives in Georgia schools involve the implementation of the Common Core State Standards (CCSS) that involve a focus on improving literacy in science (Anderson, Harrison, Lewis & Regional Educational Laboratory Southeast, 2012). Soon to follow, science teachers in the State of Georgia will be required to implement a new curriculum based on The Next Generation Science Standards (NGSS). The NGSS are the new national standards for science, released in April 2013, that identify content, science, and engineering practices necessary for all students in grades K-12 (Achieve, Inc., 2013). In addition to the state and national mandates, teachers are often faced with local initiatives intended to meet the needs of a particular school or school system.

Purpose of Study

The purpose of this study was to gain a better understanding of the culture of science education and how this culture informs teacher practice in the secondary science classroom. This study took an anthropological look at the lives of science teachers in a small rural school. Ethnographic case study was used to define the culture of science education within the context of a school setting. Case studies in education incorporate theoretical perspectives and techniques from a variety of disciplines, including history, sociology, and anthropology (Merriam, 1990). The examples of ethnography and other anthropological study found in literature on the culture of science provided a foundation for this study. The goal of this study was to enable those outside of the science classroom to develop a better understanding of science teachers' views of pedagogy and teacher practice in the classroom and of their response to changes in science standards and curricula resulting from both large scale curriculum reform and local education initiatives. This study will provide professionals in teacher education programs with information that will help prepare pre-service teachers for a career in science education. This study will also inform school administrators of the various types of stress encountered by science teachers on a daily basis and will provide insight into ways that this group of teachers attempt to cope with these stressors and strive to improve student learning in their classrooms. Although this is an isolated case study, this research has the potential on a broader scale to provide science teachers with an awareness of the factors that influences their own choices.

Research has demonstrated that teachers' beliefs about curriculum reform are crucial in design and implementation of new curricula (Van Driel, Bulte, & Verloop, 2008). As with the world of science, these beliefs and traditions are part of the culture within which science teachers live and work. The purpose of this study was to allow the teachers a chance to share their story.

Where they were coming from, what struggles did they endure, and what informed and impacted choices that they made regarding pedagogy? Understanding the teachers' perspectives might aid in eliminating factors that lead to attrition and burnout (Jepson & Forrest, 2006) and enable teachers to cope more easily with large scale reform, local initiatives and other demands for change.

Research Questions

This study sought to understand the culture of science education from the perspective of science teachers in a small rural high school. Observations, interviews, and conversations with these teachers allowed each to share his or her individual experiences in both becoming and being a high school science teacher. A grounded theory approach was used to answer the following questions:

1. What defines the culture of science education?
2. How does the culture of science education inform teacher practice?

Answering these questions in a case study setting provided only a small pixel of a much grander image. However, the depth of the study allowed for a clear and intimate picture of a science teacher's daily existence.

Definition of Terms

1. Cognitive apprenticeship (Brown, Collins, & Duguid, 1989) is similar to traditional master-apprentice relations in which the apprentice learns from the master of a trade. However, cognitive apprenticeship embodies both the practices of the master(s) and the development of cognitive skills essential for achieving full participation in a community of practice.

2. Community of practice in this study serves as a context for understanding the relationships among teachers in an educational setting (Lave & Wenger, 1991). The relationships, interactions, and social situations that occur within the community engage participants in a process of learning that enables them to become functional members of that community. For the purpose of this inquiry, the community of practice consists of four science teachers in a small rural school along with others whose membership is identified vicariously through the stories of these four teachers.
3. Constraints, both in science and in science education, are aspects of the culture, either internal or external, that invoke restrictions on practice. Galison (1997) explained that constraints are not limited to the restrictive role, but can also play a constructive role, providing both structure and direction to a research program.
4. Reform is a term used to describe change in standards for educational practice. Reform on the federal and state level involves large scale changes in standards and guidelines for teaching. Requirements or recommendations are delineated in publications such as *National Science Education Standards* (NRC, 1996), *Benchmarks for Science Literacy* (AAAS, 1993), and more recently, the *Framework for K-12 Science Education* (NRC, 2012) and the *Next Generation Science Standards* (Achieve, 2013). For the purpose of this study, reform is seen as one of many catalysts for adding or changing expectations for science teachers at the local level.
5. Situated learning (Gee, 2001; Lave & Wenger, 1991; Wertsch, 1998) is based on the concept that learning is not independent, but occurs within the context of practice. Participants engage in, and simultaneously learn from, activities and interactions within the social context of the community in which they are practicing. The term situated

cognition (Brown, Collins, & Duguid, 1989) extends the concept of situated learning to define how participants negotiate meaning of what is being learned.

6. Sociocultural perspectives involve the social interactions that occur within a given culture and how those interactions help to build meaning within the culture. This includes the values, beliefs, ethics, and standards established by the community (Goodenough, 1970; Vygotsky, 1978; Wertsch, 1998).

Assumptions

The purpose of this research was to investigate the culture of science education in a small rural school. A grounded theory approach was used with a constant comparative method (Glaser & Strauss, 1967). Because this is a grounded theory, the data informed and guided both the choice of literature and the questions and observations that occurred during the study. Primary means of data collection included one-on-one and group interviews in addition to participant observation in multiple social situations (Spradley, 1980) including the classroom, hallways and doorways, and other locations throughout the school.

It was assumed that all science teachers participating in this study are members of a community of practice in which they work together to ensure that students obtain an appropriate science education within their school. Being a member of this community of practice involved certain practices/criteria that are both spoken and unspoken. It was through their actions in the classroom and within other social interactions that their membership was determined by others within the group. Learning to engage as a full participant of the community involved the process of cognitive apprenticeship where participants develop the cognitive and technical skills within the social context of the community (Brown, Collins, & Duguid, 1989). For those who are not yet proficient in the expectations of the group, full participation is something they strive to achieve. These members participate on the peripheral, learning from the group and working their way towards full participation (Lave & Wenger, 1991). All participants in this study have more than ten years of classroom teaching experience and had reached what could be considered full participation. Yet, even as full members, participants are continually learning from and adapting to the demands of the community. Lave and Wenger state that “change is a fundamental property of communities of practices and their activities” (p. 117). Therefore, all members of a community, both veterans and new participants, are continually learning from the culture in which they practice.

This study, similar to many in the culture of science, uses a social constructivist approach (Cetina, 1999; Galison, 1997; Lave & Wenger, 1991; Latour, 1987; Vygotsky, 1978) that assumes knowledge was learned within the context of practice. Teachers in this study have learned how to teach science throughout their experience and participation in both the culture of science and in the culture of science education. It was within the culture of science education that they learned what and how to teach, how to interact with students and manage a classroom effectively, and how to integrate strategies and curricula that are passed down from the national, state, and district levels. Learning occurs in the classroom and through social interactions with other science teachers, scientists, educators, and administrators that are participants within their various communities of practice (Lave & Wenger; Wenger, 1998). It was through participation in these communities of practice that teachers develop knowledge about accepted practices, content, and pedagogy.

The culture of science provided examples of social constructivism as well through ways that scientists participate within their respective communities and in the acquisition of scientific knowledge. Galison (1997) establishes that scientists in the field of physics, for example, adhere to traditions within their community that are passed down from mentor to apprentice similarly to what Lave and Wenger (1991) describe in their concept of communities of practice. Within the various scientific disciplines, communities of practice may form around a single research tradition, a common interest, specialized fields of study, or even instruments used in the laboratory. Junior scientists learn to become veteran/senior scientists through their participation in the community of practice, learning from those who are considered experts in the field and passing on traditions of practice to the next generation of scientists. As established in Galison and Stump (1996), the boundaries separating the traditions in the culture of science are strictly safeguarded by loyalty and the confines of instrumentation.

The theory of situated learning was used to describe the participation of each teacher within a community of practice (Lave & Wenger, 1991; Wenger 1998). The concept of communities of practice provided a foundation for understanding the interactions that occur among the participants in this study. It was assumed that the four science teachers participating in this study form a community of practice. Members of this community of practice maintain certain expectations of others who hold membership in the group. These members also hold expectations of those who engage in social interactions with this community, including teachers of other subjects, school and county administrators, students, and other school staff. These expectations are focused on what is necessary to ensure that they are capable of performing their duties as science teachers. Within this community of practice, the participants learn from each other and make meaning out of what it is to be a science teacher and a member of this particular community of practice. It was assumed that the social interactions that occur within the community of practice contribute to learning to teach science. New teachers learn from veteran teachers, and vise versa as each forms his/her identity as a science teacher and member of the community. They also learn from other teachers outside of their immediate community of practice and apply this knowledge to their craft and share with others within their community of practice so that a successful teaching strategy is passed along as an acceptable addition to the community's repertoire. It was assumed that members of the community of practice may not always agree on strategies and approaches to teaching science. Actions and interactions that occurred within the community of practice, along with interviews and conversations with participants helped to describe each teacher's individual identity within the community.

Significance of Study

The significance of this study lies in its focus on the teacher as a member of the culture of science education. It asked what defines the culture of science education from the perspective of teachers in the field. Understanding where the teachers are coming from and the concerns that influence their day-to-day practice will provide insight into what they value and what they might need in the way of support from the administration and other officials that could influence their experiences in a positive way. Science teachers are faced with a myriad of changes with potentially stressful consequences. Issues of change have been shown to be a significant factor contributing to teachers' stress levels (Brown, Ralph, & Brember, 2002). Schools in Georgia are striving to implement new curricula in the form of Common Core State Standards, and soon to follow, the Next Generation Science Standards will be incorporated into the Georgia curriculum. As science teachers learn and implement the new curricula associated with the CCSS and the NGSS (Achieve, Inc., 2013), it is necessary to gain a better understanding of the cultural aspects that influence teachers' choice of pedagogy and approach to teaching science.

Summary

Science education is always under scrutiny and is always changing. Teaching science requires that the teacher be familiar with appropriate pedagogical strategies, the latest in science content, and tie these both to the most recently developed curriculum standards. Teachers must meet the challenge imposed by this culture and continue to ensure that their students are learning at their best. The purpose of this study was to gain a better understanding of the cultural aspects that influence teachers' choice of pedagogy and approach to teaching science in secondary schools. This study sought to define the culture of science education and to better understand how this culture informs teacher practice in the science classroom.

Science teachers are members of various communities of practice including both education and science. It is through participation in these communities that science teachers develop knowledge and skills necessary to be a successful in the classroom. As members of a community of practice, teachers develop an understanding of what is acceptable practice, content, and pedagogy. They learn what is essential for ensuring student learning. With changes occurring at so many levels and at such a rapid pace, it can be difficult for teachers to keep up. In the study by Brown, Ralph, and Brember (2002), it was reported that British teachers enduring extensive curriculum changes experienced "bewilderment and angst at the scope and rate of change" particularly related to the apparent "irrationality behind" reform (p. 6).When curricular changes based on large scale reform or local and state initiatives challenge strongly held values and beliefs about science teaching, responses to change may be misconstrued as rebellious or reluctance. When, in fact, these may be rooted in strong beliefs about what is best for the students. This study seeks to understand the culture of science education and how science teachers cope with the challenges and constraints imposed upon them and how it informs science teaching.

CHAPTER TWO: LITERATURE REVIEW

The purpose of this study was to define the culture of science education and determine how this culture informs teacher practice. The culture of science education was viewed by the researcher as part of the overarching culture of science, a culture from which science teachers develop scientific content knowledge and acquire some of their ideas regarding pedagogy and what is considered acceptable teaching practice for science. The culture of science involves more than developing the concepts and theories studied in a textbook. It also provides a foundation for understanding the practices, traditions, values, and beliefs held by scientists and transferred to others within that culture, including those who will someday become or who currently are science teachers. For the purpose of this study, the culture of science education was viewed as being under the umbrella of the culture of science, thus, allowing the culture of science to serve as a ballast to support the understanding of sociocultural interactions that occurred within the culture of science education. Reform initiatives and trends in science education help to outline changes in the culture of science education concerning science curricula and evaluation of teacher practice (De Jong, 2007; Yager, 2000). Research in science teaching provides insight into teaching practices that are encouraged and considered valuable to the acquisition of scientific knowledge and understanding (Alfieri, Brooks, Aldrich & Tenenbaum, 2011; Anderson, 2002; Banerjee, 2010; Burton & Frazier, 2012; Cobern, Schuster, & Adams, 2010; Dean & Kuhn, 2007; Crawford, 2007; Klahr & Nigam, 2004; Mistler-Jackson & Songer, 2000; Sanger, 2007; Trowbridge & Bybee, 1996). In addition trying to keep pace with education reform and research, science teachers must stay current on scientific discoveries and technologies that can make the teaching of science like trying to hit a target that is not only moving, but accelerating at an exponential rate.

The review of literature that provided a foundation for this study was divided into four categories. The first category highlights trends and reform initiatives in science education beginning with 1960s reform efforts that were ignited by launch of Sputnik by the former Soviet Union and spanning to the most recent innovation in science education, *The Next-Generation Science Standards.* The second category in this literature review outlines research on pedagogy and teacher practice. The strategies of teacher practice addressed include direct instruction, inquiry-based instruction, discovery learning, and laboratory work. Selection of strategies to discuss in this literature review was based on the literature in category one. These four overarching strategies were identified as being significant to reform efforts at various times in history of science education reform. Discussion of these strategies was kept general in nature to allow for comparison, connection, and contrast of more specific strategies that arise during observations and discussions with research participants. The third category examined the culture of science, including the acquisition of scientific knowledge, loyalty and traditions within the research communities, and the culture of the science laboratory. This category lays the foundation for understanding the interactions among science teachers and colleagues in this study. Finally, the fourth category emphasizes the contribution of this study to the broader field of curriculum studies. The purpose of this category is to link the social, cultural, and professional context of this study with issues pertinent to curriculum studies.

Trends and Reform Initiatives in Science Education

This chapter begins by highlighting literature in the field of science education pertaining to reform initiatives and trends that have occurred in a span of more than sixty years. This review of the history of science education is sets the stage for understanding the culture of science education. Changes in the way that society views science education, along with the ever-evolving level of involvement federal and state school boards have on the local science curriculum, has a strong bearing on what occurs inside the science classroom. These sources provided insight into ways that public school science evolved and how the emphases on teacher practices changed to meet the demands of various reform initiatives and curriculum projects. Current reform efforts that impact science education on the National level, including *The Common Core State Standards, A Framework for K-12 Science Education,* and *The Next Generation Science Standards*, were used to outline changes that teachers are currently facing in the science classroom.

Making Scientists and Engineers: Reform Initiatives of the 1960s

When the first earth-orbiting satellite, *Sputnik*, was launched in 1957 by the former Soviet Union, it became evident that science and technology in the United States was inferior to that of other industrialized countries (De Jong, 2007). This made the country stand up and take notice. Kleibard (2004) pointed out that this was viewed as an example of America's "soft" education that, at the time, focused more on preparing secondary school students for "life adjustment" rather than a rigorous study of science, mathematics, and other core subjects. The United States reacted by passing the National Defense Education Act in 1958 that called for a top-down approach that focused on the mastery of modern science techniques and principles (National Defense Education Act of 1958). This Act called for extensive revisions in key subject areas, including science, resulting in funding for programs seeking to improve science and opening the way for the first, of what De Jong calls, "waves of innovation" in science education reform.

The first wave of science education reform, often referred to as the Golden Age, had a tremendous impact on science education, both in the science content that was taught and in the preparation of science teachers (Trowbridge & Bybee, 1996). Projects such as Physical Science Study Committee (PSSC), the Chemical Bond Approach (CBA), Chemical Education Materials Study (CHEM), and the Biological Sciences Curriculum Study (BSCS) were all designed to create textbooks, teacher handbooks, lab guides, and other materials to provide a “teacher-proof” science course. In the fifteen years following the launch of *Sputnik*, an estimated five billion dollars was spent supporting initiatives to improve science education in grades K-12 (Harms & Yager, 1980). More emphasis was placed on learning science content and inquiry used by scientists and less emphasis on career awareness and preparation for life beyond secondary school. Through what seems like a distillation of science content, there was an attempt to rid the curriculum of all technology. This meant avoiding topics associated with the application of science to real life, specifically those topics that were considered career oriented and could be taught in vocational programs (Yager, 2000). This meant that concepts such as television, transportation, and communication were not considered significant subject matter for the college-bound students. The connection between science and society was severed and replaced with a sterile curriculum focused primarily on the structure of scientific disciplines.

During this same era, there was a shift from learning large numbers of facts to understanding the basic concepts of science, abstractions and theories, and acquiring basic scientific skills. The intent was for students to experience doing science through science taught as inquiry (Harms & Yager, 1980). To accommodate the change, classrooms were modified to incorporate space and equipment for students to do laboratory work (De Jong, 2007). Curriculum developers worked under the assumption that all students would be intrinsically motivated to learn science if it is presented the in the same way it is known to scientists. This was fostered by a strong emphasis on behaviorism and the belief in the effectiveness of operant conditioning, believing that by providing the correct stimulus as input, students would respond with the desired learning output (De Jong). A top-down approach was used to create a programmed curriculum designed to produce scientists and engineers that were superior to other countries (Harms & Yager). It was expected that university enrollment would increase for first year science courses. However, the result was disappointing. With only modest enrollment in university science courses and enduring complaints from schools that the content was too difficult for their students, as well as teachers, it was obvious that reform efforts did not fulfill all expectations. De Jong suggests that the strong focus on an existing ‘body of knowledge’ from the expert perspective rather than the student perspective was the key failure of this reform.

A Time to Reflect, 1970s

In the decade to follow, many in society blamed science for the political, social, and environmental struggles facing the country (Yager, 2000). By the mid-1970s, reform efforts in science had dissipated due to the lack of desired results and the struggle to teach science concepts in a way that was so far removed from students’ lives and interests. In fact, science was given very low priority compared to other core subjects such as mathematics and social studies. Within two decades, Americans had long “forgotten the wounded spirit” impaled by *Sputnik* (Harms & Yager, 1980, p. 9). Evaluations of science education, including three studies conducted by the National Science Foundation (NSF) and a series of reports for the National Assessment of Educational Progress (NAEP), were analyzed through a grant funded project known as Project Synthesis in 1978. The analysis revealed that the practices of science education did not match up to the needs of the individual students (Harms & Yager). Instead of addressing the needs of the majority, which included leaning to use science in their everyday life or becoming knowledgeable about science-related issues in society, all efforts were directed towards producing students who would pursue careers in science.

Recommendations derived from Project Synthesis include a shift of goals towards preparing students to be successful with science and technology in their everyday lives, focusing also on science and technology-related careers and the importance of making knowledgeable decisions regarding science-related political issues (Harms & Yager). Curriculum programs resulting from the 1960s reform were available, but there was no standardization of curriculum specifying which curriculum to use. It was also found that the majority of decisions regarding science education were made at the local level. Science teachers were found to have tremendous autonomy in choosing both the content and teaching strategies used in their own classrooms. Project Synthesis found that science teachers spent much of their time promoting socialization skills such as work ethic, paying attention, cooperating, and preparing for tests and very little time addressing the goals of using science in the personal, societal or career-choices arenas. The primary goal of the science teacher was to prepare students for the next course in sequence (Harms & Yager).

Reform in the 1980s and 1990s

After the lull in reform innovation experienced during the 1970s, America finally received the shockwave necessary to scare attention back towards science education. The National Commission on Excellence in Education published *A Nation at Risk* in 1983 sounding the alarm that the country's "once unchallenged" dominance in science and technological innovation was being "overtaken by competitors throughout the world" (p. 5). The report claimed that schools had lost sight of their purpose and no longer held high expectations or the discipline required to excel at those challenges. It called for all schools, elementary to university level, to incorporate more rigorous and measurable standards. Once again, the United States feared inferiority to other nations, particularly Japan and Germany (Yager, 2000). With science achievement in steady decline, it was time for a new reform, this time calling for an increase in science literacy and increased support in the areas of mathematics and science. Once again funds were poured into improving science education. However, instead of providing funds for massive reform initiatives, the National Science Foundation (NSF) shifted funding to the cognitive sciences (Yager, 2000). More emphasis was directed towards ways that students learn, their cognitive abilities, and developmental stages. This was a shift in thought from the idea that all students could learn the same way given the proper stimulus. This wave of reform promoted active learning and introduced the use of open inquiry tasks and discovery learning in the school laboratory (De Jong, 2007). Addressing the findings of Project Synthesis, there was a push to make connections between science and the experiences of everyday life including issues related to science-technology-society (STS), a concept almost completely removed from science courses in the 1960s. The emphasis was to ensure that all students received a science education that would make them productive, “scientifically literate” citizens with the capabilities of making informed decisions regarding societal issues (Harms & Yager, 1980).

The 1980s marked a turning point in science education reform. Unlike reforms of the past that had allowed for local control, the focus of science education reform centered on nation-wide standardization and more control at the state level. Project 2061, initiated by the Association for the Advancement of Science (AAAS) in 1985, paved the way for the development of nationally based benchmarks and standards in science education. In a series of publications that followed from AAAS and the National Research Council (NRC), the foundation was laid for what science should look like in K-12 schools. *Science for All Americans* in 1989, *Benchmarks for Science Literacy* in 1993, *Blueprints for Reform* in 1998, and *National Science Education Standards* in 1996 set the brickwork for states and schools to develop their own curriculum based on nationally recognized criteria. Theories of learning shifted to a social constructivist perspective (De Jong, 2007), recognizing scientific knowledge and practices as being learned through experience and social interactions. Emphasis was placed strongly on scientific literacy and learning through inquiry based activities; less emphasis on recitation of known facts and more emphasis on scientific discussions (De Jong; Trowbridge & Bybee, 1996; Yager, 2000). There was also a push for teachers to start working together, not in isolation from one another, in order to enhance science programs in schools. It was considered important for both students and teachers to have a sense of ownership in the curriculum if students were to learn science (Yager).

The Next Phase of Reform

This trek through reform history provided a backdrop for the development of teacher practices and pedagogy reviewed in the next category of this chapter. Understanding the history of reform allows for more informed connections between the participants in this study and the broader spectrum of science education as they shared their personal experiences as a science student during various eras in reform and eventually as a science teacher. With each decade came a new set of challenges, goals, and reform innovations. The next wave of reform is underway. Teachers in this study are in the midst of training for the implementation of the Common Core State Standards (CCSS) which focus primarily on mathematics and English language arts. The CCSS call for the integration of concepts from these two core content areas in the science classroom. This means more reading and writing in the sciences and more connections made regarding the use of mathematics in science.

A National Framework for K-12 Science Education (*Frameworks)* was published in 2012 and provided a framework (Padilla & Cooper, 2012) for the development of *The Next Generation Science Standards* (NGSS) that were finalized in 2013 (Achieve, Inc., 2013). The NGSS were developed on behalf of twenty-six states through the coordinated effort of the National Research Council, the National Science Teachers Association, the American Association for the Advancement of Science, and Achieve. Because the NGSS and the *Frameworks* are only recently established, these standards are not currently being used in the school, but these innovations in reform will impact the science curriculum in Georgia within the next few years. A key point to note on the *Frameworks* and the NGSS is the language regarding inquiry. Instead of stating that teachers will teach through an inquiry approach, the NGSS are written with three dimensions that rest on the "view of science as both a body of knowledge and an evidence-based, model and theory building enterprise that continually extends, refines, and revises knowledge" (Achieve, Inc.).

The three dimensions of NGSS include: Practices, Crosscutting Concepts, and Disciplinary Core Ideas (Achieve, Inc., 2013; NRC, 2011). Dimension 1, Practices, emphasize the knowledge and skill necessary to engage in scientific investigation. This dimension also incorporates engineering standards designed to stress the importance of science, technology, engineering and mathematics (STEM) fields in the students' everyday life (Achieve, Inc.; NRC). Dimension 2, Crosscutting Concepts, link the various domains of science. These include: Patterns, similarity, and diversity; Cause and effect; Scale, proportion and quantity; Systems and system models; Energy and matter; Structure and function; Stability and change (Achieve, Inc.; NRC). These concepts permeate all areas of science and provide coherence and link concepts from one field to the next. Dimension 3, Disciplinary Core Ideas, include four disciplinary areas:

physical sciences, life sciences, earth and space sciences, and engineering, technology and application sciences (Achieve, Inc.; NRC). These include the “teachable and learnable” objectives that are taught at each grade level.

Research on Pedagogy and Teacher Practice

With each new wave of reform, teachers were asked to reexamine teaching practices and focus on the goals and initiatives of the most recent reform effort. As seen throughout the history of science education reform, teacher practice does not always match up to the goals at hand. Harms and Yager (1980) established that in the decades preceding the writing of national standards, teachers maintained a great deal of autonomy both in what they taught and in the practices they used in the classroom. The purpose of this section was to identify the options available to science teachers that aid in determining how the culture of science education informs teachers’ choices regarding the different practices. Strategies discussed in this section include: direct instruction, inquiry-based instruction, discovery learning, and laboratory work. These strategies were selected based on their significance at different eras of science education reform (Ahlgren & Rutherford, 1993; Anderson, 2002; Burton & Frazier, 2012; De Jong, 2007; Harms & Yager; Rutherford & Ahlgren; Yager, 2000).

Direct Instruction

Direct instruction was and continues to be a prominently used strategy in science teaching. Even in the early eras of reform when there was a push for inquiry learning, the concept of inquiry was taught through direct instruction (Yager, 2000). Definitions for direct instruction vary somewhat, but all involve a very structured, teacher-centered form of teaching. Most literature discussed regarding direct instruction involved comparative studies either defending the use of the teacher-centered strategy or suggesting that an alternative, student-centered method such as discovery learning or inquiry, produced equal or better results in student learning (Cobern, Schuster, & Adams, 2010; Dean & Kuhn, 2007; Klahr & Nigam, 2004). Many discussions of direct instruction in the literature fell under the heading of "explicit instruction" (Archer & Hughes, 2011; Rosenshine, 1986). Direct instruction procedures were described as lessons taught through a series of steps intricately designed to ensure mastery of content. To foster learning of concepts, multiple sources indicated a series of organized steps for proper implementation of direct instruction that include a variation of the following: anticipatory set, discussion of specific learning outcomes or goals, presenting concepts through clear and detailed explanations, checking for understanding, and allowing time for practice to ensure mastery (Rosenshine; Trowbridge & Bybee, 1996).

The negative stigma associated with direct instruction in the literature involves memorization of large numbers of facts and the use of cookbook laboratories, yet a direct instruction approach was also considered to be the primary form of instruction for leading guided inquiry activities (Cobern, Schuster, & Adams, 2010). Essentially, direct instruction, whether conducted through lecture, demonstrations, or guided inquiry, was found to be a teacher-centered form of instruction that produced, in most cases, acceptable results on student learning when done properly (Cobern, Schuster, & Adams). The primary purpose of direct instruction was to pass on knowledge that is already known and accepted, including facts, principles, and theories (Trowbridge & Bybee, 1996). Archer and Hughes (2011) argued that the term teacher-centered was intended to be misleading, contrasting against constructivists approaches that are considered more student-centered and making the case that the methods of direct instruction were indeed "focused on the student" (p. 19). Comparative studies in which direct instruction was pitted against other forms of instruction that were considered to be more student centered, such as discovery learning or inquiry, reported that students did gain mastery of the concepts through direct instruction (Alfieri, Brooks, Aldrich & Tenenbaum, 2011; Cobern, Schuster, & Adams; Dean & Kuhn, 2007; Klahr & Nigam, 2003). Arguments for direct instruction suggested that providing students with explicit guidance and instruction maintained an advantage over teaching strategies that employed limited or partial guidance. Clark, Kirschner, and Sweller (2012) contended that instruction in which students receive minimal guidance leads to confusion, frustration, and the development of misconceptions, and that these outcomes can be avoided through the use of direct instruction. While the teacher-centered focus of direct instruction has its advantages, some argue that this type of instruction does not foster the type of thinking skills necessary for complex, higher level tasks (Anderson, 2002).

Inquiry-Based Instruction

Teaching science as inquiry was a key goal of curriculum change in every reform innovation from the dawn of the Golden Age to the NGSS. Although emphasis was made on scientific inquiry in the early years of science education reform, the goal has not yet been achieved at a satisfactory level. When inquiry was taught during early reform efforts, it tended to be taught through a direct instruction approach (Yager, 2000). The NSES (1996) provided a broad definition of scientific inquiry, referring to the process as a “multifaceted activity” including both the work done by actual scientists as they study the natural world and the activities conducted by students in order to gain an understanding of what scientists do. Science practices such as observing, questioning, communicating, among many others, were listed as components of inquiry. Definitions of what teaching science as inquiry meant varied from one teacher to another, but a conception of what inquiry means and the value it holds for that teacher has a strong bearing on whether teachers consider scientific inquiry appropriate practice for their classroom. Crawford (2007) approached the explanation what it means to teach science as inquiry through three primary aspects: (1) that students do science in K-12 classrooms that emulates what scientists do in their respective fields, (2) that students develop an in-depth understanding of the concepts of science, and (3) that the two aforementioned aspects be done through an inquiry-based approach. Because inquiry has repeatedly appeared in reports evaluating science education and in reform documents, science teachers exhibiting a willingness to incorporate inquiry lessons were often referred to in the literature as being reform-minded (Anderson, 2002; Crawford; Mistler-Jackson & Songer, 2000). The NGSS (Achieve, Inc., 2013) expresses its intent to provide a better explanation of what the term “inquiry” means in science, and therefore, included as one of its dimensions, a comprehensive and developmentally appropriate series of science practices to be mastered at each grade level.

Issues associated with the implementation of inquiry were discussed in Crawford’s (2007) study of preservice science teachers and their respective mentors. Her study highlighted the argument that teachers’ beliefs derived from personal experience, both in and out of the classroom, maintain a great deal of power in decisions made regarding teacher practice. More specifically, the teacher’s own knowledge of inquiry and inquiry-based pedagogy played a significant role in teacher practice along with the teacher’s beliefs about teaching and learning in general (Crawford). Teachers not only need a strong science content background, but also they must be able to understand and engage in inquiry activities themselves before they can effectively engage students in the inquiry process (Banerjee, 2010). Burton and Frazier (2012) reiterated this issue adding that science teachers have little opportunity to have inquiry modeled for them, thus minimizing their own learning of inquiry techniques and processes. Other underlying factors were found to limit science teachers’ use of the inquiry model. Time constraints, pressure to cover content, high-stakes testing, and students' lack of motivation were identified as barriers to the implementation of inquiry activities (Banerjee; Burton & Frazier).

Discovery Learning

During the 1980's, there was a strong push for a particular type of open-ended inquiry known as discovery learning. Discovery learning has been defined as a form of inquiry in which the "target information must be discovered by the learner within the confines of the task and its materials" (Alfieri, Brooks, Aldrich & Tenenbaum, 2011, p. 2). As with other forms of inquiry teaching, definitions of discovery learning vary among different sources. Trowbridge and Bybee (1996) identified discovery learning as including certain basic skills typically associated with inquiry learning such as observations, classification, taking measurements, making predictions, describing, and inferring. Discovery learning was based on constructivists learning theories that involve students learning through participating in activities involving varying levels of inquiry. Instead of receiving explicit explanations regarding scientific concepts, students are expected to construct meaning through investigating a problem or observing a phenomenon and then forming their own explanation by making connections to prior knowledge and experience. Alfieri, Brooks, Aldrich, and Tenenbaum conducted a review of comparative studies involving discovery learning and other, more explicit learning strategies. Their study revealed that results from comparisons of discovery learning to direct instruction depended heavily on how much guidance was provided during the discovery activities. Discovery activities in which learners were unassisted in their discovery were shown to be less beneficial than both direct instruction and other, more guided, forms of discovery learning. What the authors referred to as "enhanced forms of discovery," or discovery learning that involved more assistance in guiding the discovery, was considered superior to both unassisted forms of discovery and direct instruction.

Learning aids such as scaffolding, worked examples, and timely feedback were all proven to make the greatest impact on the success of discovery activities.

Laboratory Work

Another primary goal of early reform was to provide students with an opportunity to practice science in a manner similar to that of a real scientist. Laboratory activities range from very structured, teacher guided activities to full open-inquiry investigations. The practical experiences offered through laboratory work provide students with the opportunity to conduct hands-on activities, interact with other students in a social setting, and allow an opportunity to investigate scientific phenomena in a manner consistent with scientific practice. The 1980's focus on active learning included boosting the amount of time students spend doing laboratory work (De Jong, 2007). The goal was to make science more meaningful and appealing to students. In 2005, a report from The National Academies reported that high school students spent an average of one class period per week on laboratory work. Although these laboratory experiences were described as being beneficial in developing students' interest in science, the activities were found to have little depth, focusing more on scientific processes than on making meaning from the activities. Hofstein and Lunetta (2003) suggested that reluctance to incorporate meaningful laboratory activities stem from beliefs that teachers hold regarding laboratory activities, including what and how students learn and what must be done to achieve desired learning outcomes. For the purpose of this dissertation, laboratory work was viewed as any opportunity for students to work, either individually or in small group setting, within a designated laboratory area.

Summary of Teacher Practice

The four key practices highlighted throughout science education reform in the United States included direct instruction, inquiry learning, discovery learning, and laboratory work. Although this was not a comprehensive list of teaching strategies, it did provide a starting point for discussing teachers' choice of pedagogy and practice. These approaches to teacher practice, at times, seem to overlap. For example, inquiry learning was noted to incorporate varying levels of guidance, from open-inquiry that was considered a form of discovery learning to more teacher-lead guided-inquiry that serves as an example of direct instruction. Laboratory work also varied from the fully guided "cookbook-labs" to open-inquiry investigations. The goal of this dissertation was to investigate how cultural factors contribute to science teachers approach to these practices.

The Culture of Science

The purpose of this dissertation was to define the culture of science education and to determine how that culture informs teacher practice. Therefore, the literature discussed in this category was chosen to provide a foundation for defining the culture of science education and understanding the sociocultural interactions that occur within this culture. The culture of science education falls under the umbrella of the culture of science. Therefore, the culture of science was used as an overarching theme for understanding the culture of science education and for identifying the communities of practice in which science teachers participate. Within the culture of science, social and economic constraints as well as the endurance of traditions within research groups hold power over practices and pursuits of the scientific community (Galison, 1997). Not only do such powers influence what scientists do, but also indirectly affect the acquisition of scientific knowledge and what is considered to be an acceptable representation of scientific phenomena (Latour, 1999; Latour, & Woolgar, 1986). Being participants in this community of practice, science teachers are exposed to many of the same constraints that scientists experience. In some circumstances, science teachers were practicing scientists, experimentalists, or laboratory technicians before becoming teachers.

Science teachers hold a unique position in the culture of science. Osbourne and Dillon (2010) suggest that science teachers often consider themselves first and foremost as a scientist and a science teacher second. On the other hand, Brown, Collins, and Duguid, (1989) suggest that students of science do not typically participate in authentic activities of the community until reaching the advanced gradate level. According to Traweek (1988), it is not until graduate school that students begin to learn about the physics community. Therefore, science teachers with less than a master's degree in a science content area would not be afforded the opportunity to experience full participation in the culture of science. Lave and Wenger (1991) described science teachers, instead, as a "community of schooled adults" rather than a community of scientists (p. 100). In their roles as science teachers, membership in the culture of science is maintained through their own learning and dissemination of science content and practice to their students. Literature reviewed from the culture of science included accounts from historical and sociological perspectives that analyze the relationships of scientists and others that influence the construction of scientific knowledge.

Communities of practice (Lave & Wenger, 1991; Wenger, 1998) in the scientific disciplines involve theorists, experimentalists, technicians, and others scientists who practice the art of science and gain understanding of natural phenomenon both in the laboratory and in the field. The literature demonstrated how knowledge and understanding of scientific phenomena and laboratory practice were passed from one generation of scientists to the next (Bowers &

Morus, 2005; Cetina, 1999; Galison, 1987; Galison, 1997; Galison & Stump, 1996; Kuhn, 1996; Latour, 1987; Latour, 1999; Latour & Woolgar, 1986; Traweek, 1988). Issues brought to light include human and nonhuman factors that influence the choices made by scientists, the knowledge produced and published within a science discipline, when and how it is presented, and the traditions and loyalties that occur between and among groups of scientists within their various disciplines. Commonalities that emerged in the literature included the way that standards, beliefs, values, and expectations informed practice within each community. The social relationships and other factors associated with culture of science helped to provide a foundation for studying the communities in which science teachers participate.

Acquisition of Scientific Knowledge

Science presented in textbooks and used at all levels of science education present sciences as a series of achievements, laws, and theories with little to no regard for the social aspects of scientific knowledge acquisition. Kuhn (1996) argued that textbooks were designed to be persuasive and pedagogical, imparting a misrepresentation of the nature and development of science. Consequently, the works chosen for such publications imply an historical tradition in science that Kuhn argued did not exist in the first place. What is lost in the retelling of science through textbooks is the story of the scientific community, a complex social entity with strong influence on scientific practice. Presenting scientific discoveries in a sterile and objective form, as it is conveyed in textbooks and many science classes, removes it from the context of the communities of practice (Lave & Wenger, 1991; Wenger, 1998), from the sociocultural interactions and social influences that directed scientists towards the construction of scientific knowledge.

Latour and Woolgar (1986) contended that removing scientific facts from context causes it to lose meaning. Therefore, it becomes necessary to understand the social aspects of science, how scientists communicate, and how this culture influences their practice. In Keller's analysis of subjectivity in science, she singled out the concept of "discovered" as being an illusory tactic designed to remove the human factor from the construction of scientific knowledge (Galison & Stump, 1996). The term discovered implies that the concepts were there all along and required no manipulation or articulation in order to be true. In Galison's (1997) account of material cultures in microphysics, he explained that experimenters were steeped in a complex system of machines, devices, and other laboratory materials designed by humans in order to understand the natural world. Galison describes machines, the tools of science, as an embodiment of the relationships in the laboratory and their connection to the outside culture. Galison categorized these influences into two primary environments: the inner laboratory and the outer laboratory. The inner laboratory also referred to as the microenvironment, involved the individuals, practices, and machines and other artifacts directly encountered on a day-to-day basis within the laboratory. The outer laboratory extended beyond the walls of the laboratory to include the building, institution, town, and even the country in which the laboratory was set up. This was also known as the macroenvironment and included a multitude of implications from social to structural.

Scientific Communities of Practice

Scientific communities gravitate towards a central research purpose, whether that purpose aims at discovery of a new particle, analyzing environmental impacts, or deciphering genetic code. Within each community, the discoveries, devices, and practices were shown to shape and be shaped by the culture of science (Galison, 1997; Judson, 1979; Latour & Woolgar, 1986;

Rabinow, 1996; Rabinow, 1999; Traweek, 1988). Sociocultural interactions exhibited within scientific communities of practice demonstrated elements of both collaboration and competition within and among different communities that allow for the negotiation of meaning and identity within a given community. Formation of identity is related to the forms of membership within the community; while negotiability, and thus application of meaning, is derived from one's position within the social configuration of the community (Wenger, 1998).

Loyalty and Tradition

Kuhn (1996) suggested that scientists within the same research tradition share a commitment to the same rules and standards for scientific practice. Traditions are based on past scientific achievements that are accepted within a particular scientific community and provide a foundation for future practice. Kuhn explained that these traditions fit within a community's paradigm. Adherence to such traditions of practice is prerequisite to participation in that community. According to Kuhn,

> The study of paradigms…is what mainly prepares the student for membership in the particular scientific community with which he will later practice. Because he there joins men who learned the bases of their field from the same concrete models, his subsequent practice will seldom evoke overt disagreement over fundamentals. Men whose research is based on shared paradigms are committed to the same rules and standards for scientific practice (p. 11).

Participants hold strong commitments to their paradigm, and shifting to a new tradition of practice is often met with difficulty. Using the neuroendocrinology laboratory as an example, Latour and Woolgar (1986) described this as a struggle with "veteran" scientists in the community. The newer, competing perspectives of hormonal feedback were rejected due to a traditional view that there were no nerve connections bridging the gap between the brain and pituitary gland. The scientists proposing the change were newcomers to the community, for no one brought up in the traditions of their predecessors dared to question their authority.

Galison (1997) suggests that there are three levels of continuity that are reinforced within a research community resulting in the endurance of certain traditions. The three levels include pedagogical continuity, technical continuity, and epistemic continuity. Pedagogical continuity was evidenced by the tendency of students to follow in the practices and material preferences of their predecessor. Galison noted that one could "[f]ollow 'family trees' of students on each side of the image and logic divide" (p. 21). Students within the image tradition, for example, maintained loyalty to the practices and materials associated with cloud chambers and other image producing devices. Similar continuity was found in the logic tradition with very little crossover between traditions. Technical continuity involved the day-to-day workings of the laboratory. Skills and practices were said to exist as an "unbroken cluster" directly related to the devices of a given tradition. Similarly, each tradition had its own form of argumentation, or epistemic continuity. In one example, Galison described the image tradition as having a "deep-seated commitment" to producing what they called a "golden event," a single image that "commands acceptance" of the concept in question (p. 22). Argumentation in the image tradition did not meet the standards and values of the logic tradition, a tradition that relied entirely on statistical significance provided through the multiple data sets of counter devices. While traditions often clashed in disagreement about practice and forms of argumentation, both made significant contributions to science. The power invoked by the three levels of continuity in tradition made it difficult for scientists to easily change their practice. Galison clarified that traditions are not static and unchanging, but that change in practice requires time to develop.

A scientist's presuppositions regarding phenomena and laboratory procedures often lead scientists to follow in a certain direction. These presuppositions are derived from their community of practice and are transferred down from one generation to another. Presuppositions and loyalties to tradition place constraints upon the scientists and limit their view of experimentation. These are not always bad. Were it not for presuppositions, scientists would not know what to look for or have an inclination to investigate certain phenomenon. Galison (1987) described a situation in which this type of loyalty within tradition affects scientific discovery. Scientists within a given community hold loyalties to that community and follow practices that are held to be accepted within their own community of practice (Lave & Wenger, 1991; Wenger, 1998), to employ new concepts or practices takes time. Galison recounted the experiments of Robert A. Millikan, a Nobel laureate physicist known for his work on measuring the charge of an electron. Millikan's views and presuppositions, Galison suggested, informed his practice and had a direct impact on his experimental physics. When taking measurements on the charge of electrons, Millikan would often discard data that he felt to be "less than ideal" or unreliable based on his own presuppositions, whereas another physicist might have regarded the data as reliable (p. 88). Those who supported and often held the same views as Millikan were those from his own immediate community. When opposition mounded against Millikan, one of his Ph.D. students, Carl Anderson, was noted for coming to Millikan's defense on a number of his arguments. Anderson remained loyal until Millikan's death. After which, Anderson began to break publically with Millikan's predictions.

The culture of science provides many examples of communities of practice (Lave & Wenger, 1991) that shed light on the sociocultural interactions involved in the production of scientific knowledge. Understanding the social and cultural relationships associated with the culture of science (Galison, 1997; Latour & Woolgar, 1986; Rabinow, 1996, 1999; Traweek, 1988) provides a foundation for interpreting the interactions associated with the culture of science education.

Curriculum Studies

This section focuses on the potential this study holds for the field of curriculum studies in three overlapping concerns: (1) providing an avenue for connecting the cultural studies of science to science pedagogy, (2) understanding the power struggles that impact teacher practice, and (3) enabling science teachers to develop an awareness of how the culture of science education influences their own practice. Pinar (2004) recalls that the focus of curriculum studies since the 1970s has focused on the concept of curriculum as a conversation, understanding curriculum based on research and theory that is independent of legislation, and an emphasis from teaching to curriculum. Issues associated with race, gender, class, and religion have infiltrated issues in curriculum and education throughout United States history (Apple, 1999). It is through the field of curriculum studies that these issues can be critically analyzing and the accepted norms and practices can be called to question.

While the cultural studies of science draw attention to the social aspects of scientific knowledge acquisition, it is seen by some curriculum studies scholars as devoid of efforts towards science pedagogy (Weaver, Morris, & Appelbaum, 2001). Weaver argues that the cultural studies of science "has failed to challenge the pedagogical style of traditional enlightened science" (p. 19). He calls for a new pedagogical approach that will enable students to understand the human aspects of scientific discovery and the construction of scientific knowledge. Appelbaum suggests that addressing science education through the cultural studies of science evokes concern about the "loss of traditional science in efforts to dilute science content" (p. 111). He suggests that science educators have little or no exposure to the cultural studies of science and are informed primarily by traditional science courses that focus on science content. When addressing curriculum, the primary issue of concern is on sequencing of content and skills and foundational knowledge, rarely incorporating “controversies about the nature of science” (p. 113). The view of science education presented in curriculum studies suggests that by omitting the cultural studies of science from science pedagogy, the modernist view of science is perpetuated throughout science education. In this dissertation, the cultural studies of science provide a resource for understanding how culture informs teacher practice and views the culture of science education as part of the culture of science.

The field of curriculum studies sheds light on what David Blades (1997) calls “procedures of power in the curriculum-discourse” that work to “secure the status quo” (p. 125). In curriculum practice, Pacheco suggests that “practices are controlled intensively and persistently by administrative agendas” (p. 14). This suggests that the science curriculum, the content and the way it is taught in the classroom, are evidence of such power. Blades explains that power is not given to individuals, rather it is defined by a “system of force relationships” (p. 101) that govern the behavior of individuals within a system or organization. There are hidden stories behind the curriculum-discourse that can help illuminate these procedures of power (Blades). This dissertation uses the hidden stories, the perspectives of individual science teachers, to investigate what informs their practice.

Greene (1978) stresses the importance of becoming cognizant of situations and associations within our own lives. Developing consciousness of social situations enables a person to better cope with issues and changes that occur in their lives. Greene calls for a “critical reflection” that allows individuals to develop an awareness of the situations in which they live and work. She argues that to develop such awareness, the individual must obtain a certain “degree of wide-awakeness too many people avoid” (p. 17). Jardine (1998) suggests that to fully understand life as it is lived, the individual must disconnect from the culture and society and “reconnect with it only in those ways that render it our predictable and manageable object” (p. 9). Without such an awareness, the issue of importance could become marginalized (Jardine). This study will contribute to the development of awareness regarding the culture of science education and teachers’ choice of pedagogical strategies.

Summary

The purpose of this study was to define the culture of science education and to determine how that culture informs teacher practice in the science classroom. This literature review was divided into four categories: (1) Trends and reform initiatives in science education, (2) Research on pedagogy and teacher practice, (3) The culture of science, and (4) Curriculum Studies. Through studying trends and reform in science education, it became clear that many changes have occurred in science education since reform efforts of the 1960s. Although America experienced many advances in science, each new decade brought the realization that science education as a whole was falling short of the need to educate all students (De Jong, 2007; Trowbridge & Bybee, 1996; Yager, 2000). The history of science education reform showed a change in goals from a push to produce scientists and engineers in the 1960s to a realization in the 1980s that developing scientific literacy for all Americans was essential to the political and ecological needs of the country. With a change in goals, came a change in expected teacher practice. Research on pedagogy and teacher practice in science classes demonstrated that direct instruction, inquiry-based instruction, discovery learning, and laboratory practice can each be effective forms of instruction in science classrooms (Ahlgren & Rutherford, 1993; Anderson, 2002; Burton & Frazier, 2012; De Jong, 2007; Harms & Yager; Rutherford & Ahlgren, 1990; Yager, 2000). Issues brought to light in the literature review that influence teachers’ choice of practice include: teachers’ experience using the practice, the teachers’ own content knowledge, time and other constraints, and the teachers' own values and beliefs regarding a given practice. It is the goal of this dissertation to determine how the culture of science education informs teachers' choices regarding these practices. The culture of science was used to help define the culture of science education. Sociocultural factors associated with the scientific community were used to provide a foundation for understanding the communities of practice (Lave & Wenger, 1991; Wenger, 1998) in which science teachers participate. The unique position science teachers occupy in the culture of science requires that they both learn from and reproduce that culture as much as possible to teach their students.

CHAPTER THREE: OVERVIEW OF THE STUDY

The purpose of this study was to better understand the culture of science education through the eyes of the science teacher and to investigate how this culture influences teacher practice. This study was inspired by the anthropological and historical perspectives of scientists described in the culture of science, particularly from literature in the field of science studies. Subsequently, the study investigated the culture of science education through the perspective of science teachers in a small rural high school. To do so, this inquiry utilized an ethnographic case study (Denzin & Lincoln, 2003) to analyze social interactions and events that occur within the culture. A social constructivist perspective helped to frame the inquiry (Vygotsky, 1978) based on the premise individuals obtain knowledge and learn to function within a given culture based on experiences and social interactions within that culture (Goodenough, 1970). The foundation for understanding the interactions was based on the concept of a community of practice (Lave & Wenger, 1991) in which all four science teachers that work in this small rural high school are all full participants. Subsequently, the relevant methodological components as a foundation for this study were organized into separate sections.

First, the chapter addresses the theoretical perspectives that helped to frame this study and to investigate the researcher questions. The chapter then establishes the importance of using a qualitative research design in the tradition of case study. Next, the chapter discusses the context in which this study occurs, providing a description of the school (research site), how entry was gained, and a description of the researcher and participants along with an explanation of the science programs offered at the school. This is followed by a brief timeline over which the inquiry will take place. Next, the chapter addresses the research procedures including the data sources and data collection procedures used in the study. A brief explanation of data analysis is provided followed by sections addressing the limitations, delimitations, and integrity of the research (Lincoln & Guba, 1985).

Theoretical Frameworks

The conceptual framework that informed this inquiry included both an ethnographic perspective (Denzin & Lincoln, 2003; Geertz, 1973; Goodenough, 1970, 1981; Lincoln & Guba, 1985; Merriam, 1990; Stake, 1995) and a social constructivist perspective (Lave & Wenger, 1999; Vygotsky, 1978; Wertsch, 1985). Together, these perspectives provided a conceptual framework that directed attention of the researcher (Eisner, 1991) to better understanding of the culture of science education. According to Eisner, the use of multiple perspectives allows the researcher to understand the situation from different frames of reference and see different view points on the issue. It was the researcher’s responsibility to ensure that interpretations and conclusions are considered credible within the chosen framework (Eisner).

An Ethnographic Perspective

This study used an ethnographic perspective as a lens for understanding the sociocultural interactions of science teachers within the cultural context of a small rural high school. Ethnography utilized analyses of both the social interactions and cultural influences of the case (Merriam, 1990). It sought out meaning, beliefs, and patterns of behavior shared within the community. Geertz (1973) argues that a good interpretation of culture should take you “into the heart” of that culture (p. 18). Through the use of an ethnographic perspective, the researcher was able to provide a glimpse into the culture of science education and better represent the stories and voices of the science teachers participating in the study. This perspective made it possible to provide an in-depth presentation of the culture of science education, the interactions, artifacts, and actors.

Goodenough (1970) describes culture as not dissimilar from describing a very complex game where each person or categories of persons corresponds with a piece on the board. People within the culture, like the pieces in the game, must abide within the restrictions of the game and applicable rules. They must do so in such a way as to convey the rules and standards at a level satisfactory to those who play the game. Conducting an ethnographic case study requires that the researcher be immersed in the culture, becoming familiar with the actors and artifacts that make up the culture. The ethnography should explain the culture well enough that an outsider might understand the accepted social and cultural practices of the community. Stake (2003) explains that we come to know and understand the culture based on the experiences that others reveal to us. As a result, it becomes necessary for the researcher to establish a certain degree of trust with the research participants (Lincoln & Guba, 1985). With trust established, the researcher is able to enter the boundaries of the culture to better understand the sociocultural interactions that occur within that culture.

An ethnographic perspective was necessary for this study because it allowed the researcher to incorporate the cultural context in which the participants were working, teaching, and collaborating in order to understand how that culture impacted the choices made by the teachers. The researcher had an opportunity to observe the activities and interactions of the community, and portray the culture of science education within the context of the school. Each teacher provided a unique perspective regarding the culture of science education through their own experiences as a student of science, as a career professional in the science field and/or in the field of science education. Goodenough (1981) suggests that each individual develops his/her own personal outlook on the world, or propriospect, based on various experiences. An individual's propriospect incorporates standards that he/she has learned through experience that enables him/her to function in a socially and culturally acceptable manner within that culture. Experiences that comprise an individual's propriospect may draw from various cultures which contribute to that person's system of standards, beliefs and values (Goodenough). The teachers will be asked to share stories of trials and triumphs in their personal journey to becoming the science teacher that they are today.

A Social Constructivist Perspective

A social constructivist perspective provided the necessary lens to understand the influence of culture science education on the choices that teachers make regarding pedagogy and practice. Vygotsky (1978) suggests that the development of meaning is situational, stemming from both culture and society. The teachers in this study were immersed in a variety of social settings and situations through their work in the classrooms, throughout the school, and in their personal life. Learning is a social process (Vygotsky; Wells, 1994) in which knowledge is constructed from encounters and interactions with the human actors and nonhuman artifacts within a particular sociocultural setting (Wertsch, 1998). For that reason, this study investigated the participants' interactions with other teachers, administrators, and students, as well as maintain a focus on participants' uses of and responses to the tools and artifacts within the culture.

It is through human perception (Vygotsky, 1978) that we make sense of the world around us and learn to function within society. This process is part of our situated experience and enables us to gain knowledge about what it takes to gain full participation within a community of practice (Lave & Wenger, 1991). This concept is part of the social theory of learning in which learning takes place within a cultural context (Lave & Wenger). It is through participation in a culture that individuals make meaning and form identities. Wertsch (1991) states that "virtually all human action, be it on the individual or social interactional plane, is socioculturally situated" (p. 109). Individuals learn to think and problem solve within a social setting. The techniques used for problem solving in a social setting, for example, are internalized and reconstructed when the individual must function alone (Vygotsky, 1978). Wertsch describes the boundary between social and individual functioning as permeable, stating that even mental processes maintain a "quasi-social" nature (p. 110). Throughout an individual's life and experience in a variety of cultural settings, perceptions are categorized (Vygotsky) as part of the developmental process. This study sought to understand both the sociocultural settings in which the participants currently teach and other social and cultural that may influence the choices they make in the classroom.

The Research Design

This natural inquiry used a qualitative research design and grounded theory development (Creswell, 1994; Glaser & Strauss, 1967; Merriam, 1990; Spradley, 1980; Strauss & Corbin, 1997) with an ethnographic perspective to describe the day-to-day life and experiences of a group of science teachers. Because this study was conducted in the tradition of a case study design, the results were not intended as an archetype of all science teachers. Instead, the goal was to emphasize the sociocultural interactions, beliefs, values, and constraints of one group of science teachers in a small rural high school and to shed light on the multitude of factors that influence choices regarding teacher practice in the science classroom. Merriam stresses the significance of such perspectives in qualitative case study research stating that they are intensive and holistic in nature. Qualitative case studies enable the researcher to portray the lives of participants in context, providing insight into what it is like to be in their shoes. The research questions that guided this investigation are:

1. What defines the culture of science education?

2. How does the culture of science education inform teacher practice?

A Qualitative Research Design

Qualitative research is a naturalist approach to understanding the world (Denzin & Lincoln, 2003; Lincoln & Guba, 1985). Studies falling into the realm of qualitative research incorporate a montage of methodological practices that allow the researcher to study and make sense of things in their natural setting (Denzin & Lincoln). While some studies that involve qualitative research may also incorporate quantitative elements, the term qualitative research applies to studies or aspects of a study that generate "findings not arrived at by means of statistical procedures or other means of quantification" (Strauss & Corbin, 1990, p. 17). A qualitative research design is appropriate for this study because the study sought to understand the culture of science education and how this culture informs teacher practice. Through a qualitative research design, this study explored a multiplicity of human and nonhuman elements that exist within the context of this school and that have potential influence on the sociocultural activities within this community of practice (Lave & Wenger, 1991; Wenger, 1998).

Eisner (1991) identifies six features indicative of a qualitative study. These include: *field focused, the self as an instrument, interpretive character, the use of expressive language, attention to particulars*, and *coherence, insight, and instrumental utility.* This study incorporated each of these features to varying degrees.

Field focused. The research took place within the setting of a small rural high school. The researcher went out into the school to observe the human actors and their social interactions. In addition to the human component of the culture, the researcher also focused on the inanimate objects (Eisner, 1991) such as textbooks, room décor, the overall layout of the school, and any artifact that was part of the culture. Spradley (1980) explains that, when studying culture, the researcher must distinguish among “three aspects of human experience: what people do, what people know, and the things people make and use” (p. 5). The researcher conducted activities in the field that were consistent with Eisner’s description that includes observations, interviews, descriptions, and interpretations.

The self as an instrument. This study related to the second feature of a qualitative study, *the self as an instrument,* because the researcher had to make sense of the social interactions and activities that were observed in the field (Eisner, 1991). In this study, the researcher was an instrument of data collection (Creswell, 1998) that uses multiple qualitative methods to evaluate meaning (Lincoln & Guba, 1985) and better understand the culture of science education. The researcher had to make sense of the culture and “pick [her] way” (Geertz, 1973) through what is being observed and collected in the field in order to provide an authentic representation of the social interactions of that culture. Guba and Lincoln (1981) posit that the strength of using the evaluator as primary instrument in the study is that he/she maintains a multidimensional quality that is responsive to cultural activities.

Interpretive character. This study maintained an *interpretive character,* meaning that the researcher was required to make meaning of what was being observed and provided an explanation that imparts an understanding of why these things occur (Eisner, 1991). The researcher utilize thick description (Geertz, 1973) to provide an account of what was taking place in the culture, going past a superficial description to “make sense of what is going on in the culture” (Erickson, 2002, p. 59). As social situations arise, the researcher was responsible for ensuring an accurate portrayal of each activity, whether she was describing a formal science lesson or a brief encounter between two teachers passing in the hallway. It was necessary for the researcher to interpret and construct meaning (Eisner) from observations of science teachers in a variety of social situations (Spradley, 1980).

The use of expressive language. The fourth feature Eisner described was *the use of expressive language*. The use of expressive language provided the reader with a better understanding of what the participants were experiencing.

Attention to particulars. *Attention to particulars* was the fifth feature of a qualitative study (Eisner). Because this study was conducted in the tradition of case study, it was by nature descriptive and particularistic (Merriam, 1990; Yin, 1993, 2009). There was no attempt to generalize this study to the greater population. Instead, the study focused on the distinctive characteristics of this unique case (Eisner).

Coherence, insight, and instrumental utility. The sixth and final feature was that a qualitative study must be believable. This was accomplished through *coherence, insight,* and *instrumental utility* (Eisner). This study incorporated multiple data sources to ensure that the study was both trustworthy and valuable (Lincoln & Guba, 1985).

This qualitative study maintained an emergent design (Lincoln & Guba, 1985) that allowed the researcher to determine meaning from the context of study. Research activities that were used in this inquiry included questioning, collecting data, recording data, and analyzing data. These procedures were repeated continually in an effort to sharpen the focus of this inquiry (Spradley, 1980). Eisner (1991) proposed the following about qualitative research:

> It is an approach to the social world that accepts its dynamic and living quality. We acknowledge that what we believe to be the case enjoys only a temporary status. Social situations are in a state of flux. This does not mean that conclusions drawn about schools, classrooms, teachers, or students have only a brief and fugitive life. It does mean that qualitative inquirers do not seek those universal, invariable, and eternal natural laws represented by the aim of physicists. Ours is a "softer," more malleable universe—or a collection of them (p. 39).

This study was conducted within the boundaries of a case study and was representative of the researcher's understanding of the culture of science education as interpreted from data obtained within the context of this study.

Case Study

This study was conducted in the tradition of case study (Merriam, 1990; Stake, 1995; Yin, 1993, 2009). An ethnographic case study enabled the researcher to select a single group and to expound upon the culture of that group to a point that the reader gets a sense of the experiences, concerns, and context of the group. The use of case study allowed the researcher to investigate the complexities of the social group and provide a holistic and rich description of their activities and social interactions (Merriam; Stake; Yin). Looking more deeply into the case at hand, the researcher provided a rich description of the culture of science education that was not broad and generalized to the greater population, but one that was narrow and deep rooted within the experiences of the science teachers in this single case study. This case study was bounded (Merriam) in the fact that the study focused on a group of four teachers collaborating within the same community of practice (Lave & Wenger, 1991; Wenger, 1998).

Stake (1995) identifies three types of case study research: *intrinsic case study, instrumental case study,* and *collective case study.* The first type, intrinsic case study, is a study conducted because the case holds an intrinsic value or interest for the researcher. The case is chosen based on something that makes it special or interesting and not because it is representative of any other case or phenomenon. The second type, instrumental case study, is used to provide insight into a particular issue, placing the case in a position of secondary interest (Stake). Stake explains that the case "plays a supportive role" (Denzin & Lincoln, 2003) aiding the researcher in understanding some other interest. The third type, collective case study, uses multiple cases to investigate a more general issue or phenomenon. Both intrinsic case study and instrumental case study apply to this study. Stake suggests that these two types of case study research are “separated by a zone of combined purpose” (Denzin & Lincoln). Stake establishes one of the most important points to remember regarding an intrinsic case study is that the case is “dominant; the case is of the highest importance” (Stake, p. 16). In an intrinsic case study, the goal is not to establish a generalization for understanding other cases. In this dissertation, the researcher maintains a particular interest in the choices made by the participating science teachers in a single case, and while the study seeks to define the culture of science education, the parameters of the study limit the investigation to four science teachers within the context of one high school. This will allow for a deeper understanding of the case in question.

Grounded Theory

This study utilized the systematic procedures of grounded theory development (Glaser & Strauss, 1967; Strauss & Corbin, 1997; Strauss & Corbin, 1990) to analyze the data and provide a densely constructed account of how the culture of science education informs teacher practice. Through an inductive analysis such as grounded theory, the researcher identified patterns that occurred within the data (Patton, 1990) without imposing presuppositions about what the data might show. The initial coding procedures of grounded theory were inductive in nature (Strauss & Corbin, 1990), a process in which the researcher broke down each source of data, line-by-line, and continually asked questions regarding what was actually occurring in that situation. This initial stage of analysis led to identifying groups of concepts that were then clustered into specific categories based on their properties. Once concepts are grouped into categories, the researcher identifies similarities and differences among the categories (Strauss & Corbin). These concepts provide the foundation for building theory. In grounded theory, the researcher allows themes to emerge directly from the data as patterns begin to emerge (Strauss & Corbin).

Research Context

Braxton High School (a pseudonym) is county-wide high school situated just outside a small rural town in southeastern United States. According to 2010 census, there are approximately 11,000 people residing in the county, 26% of which are under the age of 18. The racial make-up includes 72.5% White, 25.7% Black, 11.1% Hispanic or Latino Origin, 0.6% Asian, 0.1% American Indian, and 0.1% Pacific Islander. The median household income for the county is $37,315, and the percentage of individuals below the poverty level is 19% compared to 16.5% for the state.

Braxton High School is a county-wide school with a student population of approximately 500 students in grades nine through twelve. Demographics of the student population include 54% White, 28% Black, 13% Hispanic, 4% Multiracial, and 1% Asian. Students eligible for free or reduced lunch make up 66% of the school population. Over 20% of students in the school receive some type of remedial education through the Special Education Program, English to Speakers of Other Languages (ESOL), or Other.

Like many schools faced with issues of accountability, this Braxton High School has endured its share of frustrations and adaptations in an attempt to make Adequate Yearly Progress (AYP). According to the Georgia Department of Education, this school is listed as “Needs Improvement Year Five (NI-5) or Greater.” Mandates associated with being an NI-5 school include “State-Directed” status including “loss of local governance and other additional consequences as determined by the GaDOE” (GaDOE, 2009, p. 12). These consequences could include anything from intensive mentoring and intervention by State-assigned officials to the full replacement of faculty and/or administrators throughout the school.

The Researcher

The researcher in this study has a background in teaching science at the secondary and post-secondary level. The researcher taught high school science for eight years and maintains a Georgia teacher certification for grades 6-12 science with an endorsement in gifted science in-field and has completed course work necessary to teach advanced placement biology. As a high school teacher, the researcher was awarded the honor of Teacher of the Year for her school and represented her science department by serving as Lead Teacher for the Partnership for Reform in Science and Mathematics (NSF-PRISM), a grant sponsored by the National Science Foundation to provide professional learning opportunities for teachers of science and mathematics. During this time, the researcher worked closely with professors from Georgia Southern University to write grants and develop professional development workshops designed to enhance teachers' skills both in the use of computer based laboratory technology and in teaching science as inquiry.

The researcher joined the college of education faculty at Georgia Southern University in Fall of 2007, teaching both science content and methods courses for pre-service teachers. In addition to her regular teaching schedule, the researcher collaborates with instructional technology faculty to provide much needed technology training for pre-service teachers. This work has led to presentations at two international and one national conference, also resulting in a peer reviewed journal publication. In 2013, a paper presented at the Association for Science Teacher Education (ASTE) International Conference was nominated as a finalist for the National Technology Leadership Initiative (NTLI) award. Additionally, the researcher has worked in collaboration with instructional technology faculty at GSU and a science education professor from University of Manitoba, Canada to develop a rubric for evaluating iPad apps for the science classroom. Since 2010, the researcher has served as Co-Principal Investigator for the Improving Teacher Quality grant, Teaching Using GSTC. This grant provides for a graduate level course taught in collaboration with the education, research, and veterinary staff of the Georgia Sea Turtle Center on Jekyll Island and is designed to provide classroom teachers with hands-on experience doing the work of real scientists as they strive to preserve the populations of nesting sea turtles on the Georgia coast.

The researcher holds a masters degree in Science Education and has completed all course work required for the doctoral program in Curriculum Studies. Through the curriculum studies program, the researcher has developed an interest in the culture of science and the sociocultural interactions that influence the construction of scientific knowledge and understanding. This led to questioning of how the culture of science education might influence teacher practice. The researcher brings to the study years of experience as a teacher participating in the culture of science education. As a high school teacher and as a university instructor, the researcher has utilized a wide variety of pedagogical strategies and approaches to teaching science. She has also worked in close collaboration with other science teachers in the field and has experienced the teaching of many professional science educators in her own path to becoming a science teacher.

The Participants

Four science teachers from a small rural high school participated in this study. The teacher participants came from a variety of educational and career backgrounds. Three of the four teachers obtained degrees in a science field before pursuing education. Two worked in a laboratory, and the third was a research scientist in the field of entomology. The fourth teacher obtained his degree in science education, but also held a degree in kinesiology and served as both a basketball and tennis coach. Each had a minimum of ten years experience as a high school science teacher and a minimum of five years teaching in this school. Therefore, the group as a whole has been working together for no less than five years, while two of the teachers have worked together for nearly two decades. During this time, these teachers have experienced several changes in both colleagues in the science department and in administrators at both the school and district level. The science courses taught were based on the graduation requirements for high school students in the state of Georgia. Through the years that these participants have taught, the science curriculum for the state of Georgia has undergone changes, but the courses taught at the time of this study were based on the Georgia Performance Standards for science. Participants and the courses that they taught are represented in the following table:

Table 3.1

Participant Information

Name	Courses Taught	Degree/Qualifications
Emma	Physical Science Physics	B.S. Biology, Medical Technology M.Ed. Secondary Science
Ruth	Chemistry Physical Science	Ph.D. Acarology, BS Journalism
Dale	Biology Environmental Science Physical Science	B.S. Education, Secondary Science M.Ed. Kinesiology
Christy	Biology Human Anatomy & Physiology	B.S. Biology

**Sections on degree/qualifications and years of teaching will be completed once data is collected.*

Their willingness to sacrifice time and energies to provide the researcher with a glimpse of the culture of science education within the context of Braxton High School's science department was greatly appreciated. The following introductions provide a synopsis of how each individual came to be a science teacher, his or her teaching and other career experience, and a short description of the class load and duties that he or she was involved in at the time of the study. As the results are presented in chapter four, reference will be made to comments, actions, and interactions of these four teachers. The foundational information provided in this section provides a platform for understanding the role of each participant in the community of practice (Lave & Wenger, 1991).

Christy. Christy began her career as a science teacher in fall of 2000. After receiving a Bachelor of Science degree in Biology, she worked for a year in her field and decided that she didn’t like it. Although she had no training in education, she took the Praxis and began her teaching career with a provisional certification. To obtain full certification, she was required to take foundational courses in education at the local university. After three years and a few formal observations, she obtained her T4 teaching certification. Christy taught at two other schools before coming to Braxton High, where she was completing her third year. The former schools were much larger, with the last school having a student population of over 1500. At the time of the study, Christy had three children, two in elementary school and one under the age of two years. Other than the normal duties assigned to teachers, Christy was not working with any clubs or groups at the school. Her regular course load involved biology and human anatomy and physiology. At the time of this study, Christy was teaching two sections of biology and one section human anatomy and physiology.

Dale. Dale received a Bachelor of Science in Education with an emphasis in secondary science, taking a broad range of basic science courses, mostly biology, at the undergraduate level. He also earned a Master of Science in Health and Kinesiology and was certified to teach heath in all grades Pre-K through 12. After doing some coaching, Dale enjoyed working with young people so much that he decided to become a teacher. Dale taught at two different schools before taking a position at Braxton High. His experience included teaching in North Carolina as well as Georgia. He described one of the schools as having a big science department, approximately 7-8 teachers, and the other was much smaller. Although his primary emphasis was biology, his course load included all of the environmental science courses. The remainder of his schedule was filled with sections of biology or physical science as needed. In addition to his teaching duties, he was the head coach for varsity boys' basketball and varsity tennis. At the time of this study, Dale was teaching two sections of environmental science and one section of biology. Basketball was nearing the end of the season, and tennis practices were just beginning for the year.

Emma. Education was a second career for Emma, who worked in the field of medical technology before going back to school to become a teacher. With a Bachelor of Science in Medical Technology, she had enough content courses in her background to teach both science and mathematics at the middle grades level, but she took additional courses to become certified in geography as well. Although it was not required, Emma also took curriculum and methods courses for secondary because she planned to pursue a position as a high school teacher. While she was offered the option of conducting a year-long internship on a provisional certification, she chose student teaching as the final step in her path to becoming a teacher. After student teaching, she was hired at Braxton High and has taught in the county for the duration of her 19-year career. After several years, she returned to the university to receive a Master of Education degree in Secondary Science. The initial choice to change careers from medical technology to education was made to give her a more flexible schedule to spend time with her children. At the time of this study, her youngest child was in high school. Her plans after his graduation were to seek employment outside of education. The majority of Emma's classes were physical science, but she also taught physics when enough students were interested. During this study, she taught only physical science.

Ruth. Education was a third career path for Ruth. She earned a Bachelor of Science in Biology before pursuing a Master's degree. Just prior to completing the degree, she decided to pursue a Ph.D. in Acarology, a study in the field of entomology that focuses on ticks. While working on her dissertation, she taught courses at the university and, for fun, started taking classes in journalism. The interest was so strong that she decided to obtain a degree in journalism as well. Ruth did an internship at the Detroit Free Press sponsored by American Association for the Advancement of Science (AAAS), and then, continued working for ten years as a journalist. Carpal tunnel syndrome and thoracic iliac syndrome halted her career as a science journalist, and she decided to step into science education. Ruth chose not to student teach, and instead, went straight into the classroom. At the time of the study, she had taught at Braxton High for 18 years. Her primary course load involved chemistry with the occasional physical science class. Drawing from her experience in journalism, Ruth was given a course for gifted students titled arts and humanities. During this study, Ruth had one section of arts and humanities and two sections of chemistry.

Gaining Entry

Gaining entry to the classroom required permission from multiple levels of authority: the teachers, school principal, and district superintendent. This courtesy was an essential part of this naturalistic inquiry (Lincoln & Guba, 1985) and was a process mandated by the Georgia Southern University Institutional Review Board (IRB) before research began. First of all, the researcher had collaborated with the teachers on many occasions, often participating in open conversations about pedagogy, practice, and personal issues during both professional and non-professional communication. The four participants were invited to participate due to the comfort level established with the group and their willingness to share personal stories freely and without fear or intimidation. Thus, a purposeful sampling technique is in place (Patton, 1990).

Per Georgia Southern University's IRB protocol, the four participants were assured that no identifiable information would be included in the research. Pseudonyms were used for protection and anonymity of all participants and locations, including the school, district, city, and county in which they teach (Lincoln & Guba, 1985). In addition, each participant was asked to sign an Informed Consent form that was approved by the IRB for this research project. The principal approved entry into the school and, before doing so, ensured that the district superintendent approved of the project. Although there was a sense of comfort and security with the teachers, the principal and superintendent were concerned with maintaining the reputation of the school within the community and beyond. Therefore, it was imperative that they understood that precautions taken to safeguard the integrity of the school's reputation. Also, the administration was informed that the intent of this research was not to evaluate the effectiveness of the school system, administrators, or its teachers or students. Because Braxton High School was an NI-5 school evaluators from the state were continually in the school observing, mentoring, and of course, evaluating their progress. The only advantage to an overabundance of outside observers was that students and teachers were accustomed to having an additional person or persons in their classroom on an almost daily basis. This made the researchers' presence seem somewhat commonplace.

The Classroom Science Programs

The Georgia high school graduation requirements mandate that all students entering high school in the 2008-2009 school year and beyond must successfully pass four units of science. The typical succession of courses in this particular school included 9th grade physical science, 10th grade biology, and 11th grade chemistry or environmental science. For the fourth science, students were allowed to choose either physics or human anatomy and physiology which were taught in the science department, or they could choose a course in agricultural science or family and consumer science which were taught in the vocational department. At all grade levels, students were given the option to take advanced courses identified as pre-AP or AP (advanced placement). Classes not classified as pre-AP or AP may be classified as an inclusion class in which there are a high number of students with special needs. In these cases, a teacher from the special education department served as a resource teacher to assist the science teacher during preparation and instruction of the lesson, when needed. Students entering ninth grade had taken precursor classes in the areas of life science (7th grade) and physical science (8th grade). Earth science was taken in 6th grade but was not a required course in high school.

Research Timeline

The timeline for the research included one full semester of observations followed by visits to the school as needed to clarify questions or categories that emerged during data analysis. Each teacher was observed for the duration of one complete instructional unit that spanned from five to ten days depending on the nature of the topic. As a non-participant observer (Lincoln & Guba, 1985), the researcher shadowed one teacher exclusively during the unit observation period and repeated the process with each of the four teachers. During this time, daily observations included morning duties and responsibilities, homeroom classes, a planning period, and one full ninety minute class. After the unit observations were complete, teachers were asked to suggest other days that they thought would be suitable to demonstrate an exemplar of their teaching practice. This allowed them the opportunity to share aspects of their teaching that were not used during the unit chosen for observation. This option spanned for the duration of the semester. The timeline for observations was dependent upon the schedules teachers had established for their lessons. The timeline for this research adhered to the following schedule:

Table 3.2

Research Timeline

Research Activities	Time Frame	Data Sources
Participant Observation	January 2011-May 2011	Field Notes
Individual Interviews	January 2011-March 2011	Audiotape, Notes, Transcripts
Group Interviews	January 2011-November 2012	Audiotape, Notes, Transcripts
Impromptu Site Visits	August 2011-November 2012	Field Notes
Clarifications of Data	January 2011-August 2013	Field Notes
Informal Correspondence And Updates	January 2011-August 2013	Field Notes
Final Correspondence and Clarifications	August 2013-October 2013	Field Notes

A certain degree of flexibility was maintained to allow the participants some choice regarding when the researcher observed their classroom teaching. Individual teacher interviews took place after the long term observations were complete at a time that was convenient for the teacher. Also, one focus group interview took place at a time during the semester that was suitable for all teachers. All interviews, both individual and focus group, occurred either during the teachers' common planning time or after regular school hours. After the initial semester, the option to revisit the site or contact participants for clarification of comments or observations remained available until completion of the dissertation. This allowed for several follow-up visits.

Research Procedure

The purpose of this study was to describe the culture of science education and how this culture influences teachers' choices regarding pedagogy and practice. This study was conducted in the tradition of case study including four participating science teachers from a small rural high school. The participants worked together as members of a community of practice (Lave & Wenger, 1991; Wenger, 1998), learning from each other and their community as they work to provide high school students with an understanding of science concepts. Through a variety of social situations and interactions (Goodenough, 1970; Lave & Wenger; Wenger) individual members of the community fill specific roles and learn to function within their culture(s) and communities. These interactions helped to define the culture of science education and allow for a more in depth understanding of choices teachers make within this culture. The researcher incorporated multiple data sources (Lincoln & Guba, 1985) and collection methods to define the culture of science education. The research procedure can be described in three overlapping phases: Phase One- Informal observations and discussions, Phase Two- Formal observations and semi-structured interviews, and Phase Three- Continued correspondence and clarifications.

Phase One began on the first site visit and continued throughout the first semester of the study. This phase enabled the researcher to establish a more open relationship (Taylor & Bogdan, 1984) with the participants and become familiar with teachers' schedules and routines. This phase involved informal conversations with participants along with observations and field notes (Spradley, 1980). These initial conversations allowed the researcher to negotiate times and spaces for observation and interviews, all the while developing rapport with the participants (Taylor & Bogdan). Each participant agreed upon a timeframe for formal observations and interviews. Once parameters were established and the observation schedule was decided, Phase One continued during the intermittent spaces, the days between and weeks that follow the formal observations. During Phase One, the researcher interacted with participants during morning duties, in the hallways and classrooms between classes, and during their planning period and lunch break. These activities provided space for the researcher to engage participants in informal interviews (Spradley) consisting of specific questions that fit appropriately within conversation and aid the researcher in understanding a particular aspect of the culture or practices. Patton (1990) explains that during these "informal conversational interviews" the researcher should remain flexible and allow questions to "flow from the immediate context" (p. 281).

Grounded theory research involves several layers of data analysis that occur throughout the data collection process (Strauss & Corbin, 1990). This means that as data was collected during Phase One, the researcher began analyzing data through transcribing and analyzing field notes, interviews, and other data sources. Analysis began with open coding, a process that allowed the researcher to break down and compare data from multiple sources. This process required that the researcher continually make comparisons among the data to develop categories that represented groups of data (Strauss & Corbin). Analysis of field notes began immediately after the first observation and continued throughout the study. It was through the ongoing analysis of field notes that each next phase in participant observation was determined (Spradley, 1980). As part of this process, the researcher continually asked herself what was going on in the data. Glaser and Strauss (1967) refer to this form of data analysis as the "constant comparative method" because the researcher was continually comparing data from one data source to another, looking for similarities and commonalities that appear in the data. According to Spradley, the researcher does not enter the “field with specific questions,” but instead, will analyze data collected in the field in order to “discover questions” (p. 33). Categories that developed through open coding in Phase One were used to construct questions for formal interviews that occurred during Phase Two.

Phase Two included observations and formal interviews with each participant. Also, the researcher conducted a formal focus group interview with all participants. Each participant was observed and interviewed separately during this phase. The timeframe for each formal observation was established with the participant and included enough time for the researcher to observe the teaching of one complete unit of instruction from the first day a topic was introduced until the final assessment was given for that unit. During Phase Two, the observations became more focused allowing the researcher to narrow the scope of the study (Spradley, 1980). This was repeated for each participant. Once the formal observations were complete, the researcher conducted individual formal interviews (Spradley) with each participant. Guba and Lincoln (1981) consider interviews to be a valuable and indispensable tool for tapping into the experience of others. Interview questions followed similar format and content for each participant, considering the contributions of each teacher to be of equal importance (Guba & Lincoln). Open-ended questions included in the interview allowed participants to expound upon issues to which they had more information to contribute. Strauss and Corbin (1990) suggest that the researcher adjust interviewing and observing to aid in determining a focus of the study. Phase Three includes the clarification, confirmation, and analysis of data. During this phase, the researcher maintained correspondence with the participants in order to clarify responses or ask additional questions that may arose during final analysis.

Data Sources and Collection Procedures

This study emphasized both the ethnographic and social constructivist perspectives as an approach to data collection and analysis. According to Lincoln and Guba (1985) a technique used by qualitative researchers for the purpose of triangulation is to utilize multiple and different sources and methods in their investigation. This allowed the researcher to have a variety of sources to use for validating evidence of one source against that of others. This process added to the credibility of the research.

Data Sources

Multiple data sources were used in this study. Patton (2002) notes that the most commonly used data sources for qualitative study are interviews, observations, and documents. Each of these data sources were used in the study producing the following sources for this inquiry: (1) interview transcripts, (2) field notes, and (3) focus group transcripts. These were generated by the researcher during and immediately following on-site interviews and observations. Secondary sources were also used whenever available. These included documentation that the participants provide to validate or support comments that they made or strategies that they employed. Examples of documentation included this study meeting minutes, school correspondence, reports, and lesson plans among other documentation.

Data Collection Procedures

Data collection procedures were broken down into the following categories: (1) observations, both teaching and non-teaching activities, (2) interviews, including individual and focus group, and (3) field notes and reflections (Merriam, 1990; Patton, 1990; Spradley, 1980).

Table 3.3

Data Sources and Data Collection Procedures

Phase	Data Collection Procedures	Data Sources
Phase One	Informal Observations Informal Interviews/Conversations	Field Notes Documents
Phase Two	Formal, Semi-structured Interviews Formal Observations	Interview Transcript Focus Group Transcript Field Notes Audio tape Documents
Phase Three	Informal Observations Informal Interviews/Conversations	Field Notes Documents

** Quantity of data sources will be included once data is collected and analyzed. This will include number of items and pages for each.*

The researcher spent as much time as possible observing and describing the context and sociocultural interactions of the participants. The schedule for data collection activities was established during Phase One as the researcher became familiar with the day-to-day routine of the participants (Taylor & Bogdan, 1984). The researcher blocked off a span of one to two weeks for each participant to observe only that teacher as he/she completed a full teaching unit. These observations were conducted during a time that was best suited to the teacher's schedule and fit well with the lesson being taught for that unit. The observations included activities that occurred during teaching and the day-to-day activities that led up to teaching the class, beginning with morning duties and responsibilities. The researcher remained on site from the beginning of the school day until the teachers' lunch break. Whenever possible, the researcher remained during the lunch break and took field notes of these casual moments of conversation.

Observations. The researcher observed the social interactions and activities of each participant. Spradley (1980) explains that observations enable the researcher to make inferences about cultural behavior and cultural artifacts. Through observations, the researcher described the actions of the participants along with the materials and tools made and used within that culture. Gold (1958) illustrates four primary roles taken by researchers during field observation. These include (1) *complete participant,* (2) *participant-as-observer,* (3) *observer-as-participant,* and (4) *complete observer*. Each provides guidelines for the researcher to follow to protect both the researcher and her role in the project. The *complete participant* role allows the researcher to assume the role of a participant without making others aware that they are being observed. The researcher develops close relationships with the participants, even "becoming" a member of their community (Gold). In this type of observation, especially, Gold warns against the temptation to take on the opinions and attitudes of the research participants. In the *participant-as-observer* role both the researcher and the participants are aware of the roles involved in the research. In this role, the researcher conducts both formal and informal observations. Time is required for the participants to become comfortable with the researcher's presence. Gold suggests that this "uneasiness is likely to disappear" once a mutual trust is developed between the researcher and the participants (p. 220). Again, Gold warns of the dangers associated with becoming too close to the participants. In this role, the researcher is often seen as "more of a colleague than he feels capable of being" (p. 221). In this situation, the researcher must leave the field to regroup and focus on what he/she observed. The *observer-as-participant* role imparts less risk of conforming to the views and attitudes of the participants. In this role, the researcher conducts observations that are more formal, and interaction with each participant is brief. Research involving this type of observation typically involves a greater number of participants resulting in a variety of perspectives. Unfortunately, the encounters are often so brief that the participants do not have time to develop the same level of comfort that is characteristic of other types of observation

(Gold). Finally, the *complete observer* role the researcher uses more observation and less participation. This role involves “minimal reactivity” on the part of the participant (Johnson & Christensen, 2008). The observer does not interact with those being observed. In some cases, those being observed are unaware of the researcher’s presence or the fact that they are being observed. For the purpose of this study, observation techniques will include a combination of *participant-as-observer* and *complete observer* (Gold 1958; Spradley, 1980). Participants will be aware of the researcher’s presence at all times. The study will begin with dialogue and informal observations that will enable the researcher to establish rapport with the participants and allow them to become comfortable with her daily presence in the school. Observations will focus on both teaching and nonteaching activities.

The researcher filled the role of *complete observer* during all teaching activities. The researcher observed each teacher for the duration of one teaching unit, approximately two weeks in which the primary focus of observations was dedicated to one participant. This was repeated for each participant. Additional teaching observations were determined by conversations with the teachers. These observations were based on activities that the teachers had planned and specific strategies he/she was willing to share with the researcher. For example, the researcher requested to see various teaching strategies. If a teacher was conducting a lab activity or performing a full inquiry lesson that was not included in the unit observation, the teacher and researcher agreed to a formal observation of that lesson. Field notes were taken during the teaching of each lesson, paying particular attention to the types of pedagogical strategies used and the individual’s approach to teaching the science content. During laboratory activities, attention focused on how the teacher conducted the lab, connections made between the activities and the content being taught, and the teacher’s reactions to students’ questions, comments, and behaviors, and any other social interactions in which the teacher participated during the teaching of the lesson. These observations provided insight for the development of questions used in the individual and focus group interviews.

During non-teaching activities, the researcher oscillated between the roles of *complete observer* and *participant-as-observer.* The distinction between roles was based on the level of involvement the researcher maintained within the conversation. Observation spaces included locations of morning duties including the cafeteria and commons area, hallways and classrooms between classes and during planning times, and other areas such as the main office, the library or any other area of the school that commanded the teachers' presence. Times for observations were limited to certain times of the day based on the researchers' schedule. Daily observations began no earlier than 7:00 am and ended at noon. On days when the schedule permitted, the researcher stayed longer to include the teachers' common lunch break. Whenever necessary, the researcher visited to observe additional lessons or to observe after school activities. Non-teaching observations included activities such as morning duties and responsibilities, communication with colleagues (both professional and casual), weekly learning community meetings, and any other action or behavior that occurs outside of teaching his/her class. Field notes were recorded during each observation.

Interviews. Interviews provided the researcher with a window into the views and concerns of the participants. Patton (1990) states that "Qualitative interviewing begins with the assumption that the perspective of others is meaningful, knowable, and able to be made explicit" (p. 278). Interviews were necessary in order for the researcher to understand how the culture of science education had influenced the teachers participating in this study. Patton discusses three variations of a qualitative interview: (1) *the informal conversational interview,* (2) *the general* *interview guide approach,* and (3) *the standardized open-ended interview.* Each variation of the interview maintained a certain degree of flexibility and control depending on the purpose and timeframe allowed for the interview. *Informal conversational interviews* are the most flexible and are of greatest advantage to the researcher when she can remain in a setting for a long period of time (Patton). These were beneficial during informal conversations with participants between classes and during their planning periods. The researcher also used a semi-structured interview that was a hybrid between the *general interview guide approach* and the *standardized open-ended interview.* Patton suggests that questions be written out in advance for *standardized open-ended interviews*, while a *general interview guided approach* typically requires only a list of questions or issues that will guide the discussion. These were not as structured as the questions for the standardized interview. The formal interviews used in this study were a combination of specific questions and topics or issues to be addressed. This combination ensured that information obtained from each participant was based on the same questions and topics, yet there was still a certain degree of flexibility for elaboration on topics that may have seemed more significant for a particular interview.

One focus group interview was conducted with all four participants present. Focus group interviews (Patton, 1990) provide an opportunity for participants to hear the responses of others and add comments beyond what they might share alone. As the responses build upon one another, it adds depth to the study. This interview was set up for a time that was convenient for all teachers, during one of the weekly learning community meetings. School protocol required that the researcher maintain approval from the school principal to be added to the learning community meeting agenda. This focus group provided teachers with an opportunity to provide collaborative responses to a few of the questions posed in individual interviews and to collectively respond to questions and topics selected specifically for the group. Additional questions that were asked during this interview were open-ended providing a chance for the group to expound upon their ideas related to the culture of science education. Because some teachers were more outspoken than others, the researcher managed the focus group to ensure that all teachers were provided with an opportunity to share on each question (Patton).

All interviews, both individual and focus group, were tape recorded to allow the researcher to maintain a more conversational approach to the interview (Patton, 1990). The researcher personally transcribed each audio recording in its entirety. Patton suggests that full transcriptions are valuable for later analysis of data. Transcriptions were paired with notes taken by the researcher during the interview to recapture aspects of the interview that could only be caught by sight (ex. facial expressions, etc.).

Field notes and reflections. Field notes are a valuable source of data in qualitative research that come directly from observations and interviews (Merriam, 1990; Spradley, 1980; Taylor & Bogdan, 1984). Glasser and Strauss (1967) describe the field worker as follows:

> The field worker who has observed closely in the social world has had, in a profound sense, to live there. He has been sufficiently immersed in this world to know it, and at the same time has retained enough detachment to think theoretically about what he has seen and lived through. His informed detachment has allowed him to benefit both as a sociologist and as a human being who must "make out" in that world (p. 226)

The researcher (field worker) devoted extensive amounts of time to observing the practices, behaviors, and social interactions of the participants in this case study. The researcher recorded field notes for each observation, interview, and conversation conducted in the field. While many notes were taken during the activities, it was not always be convenient or polite to write notes during the activities (Merriam). In these situations, the researcher recorded an account of the observation as soon as possible after the activity (Merriam; Taylor & Bogdan). Field notes included a description of the context, including the setting, people, and activities along with direct quotes or phrases that account for what was being said or done in the field (Merriam). The researcher also took note her own experiences while in the field, including ideas, reactions, and other notes that aided describing the field experience.

Spradley (1980) explains that there are different kinds of field notes. First, the *condensed account* includes notes that are recorded "on the spot" (p. 69) and represent a condensed version of what happened in the field. These notes provide the foundation for the *expanded account* in which the detail is provided to fill in the gaps of the condensed notes. Things jotted down while observing or interviewing were used as reminders to recall actions, events, and conversations that were elaborated on and completed (Spradley). Even the events that seem mundane must also be given an account. It is through these "recurrent events," Spradley claims, that we are given the best clues into the culture. Finally, Spradley stresses the importance of keeping a *fieldwork journal* to organize and maintain an account of all observations and interviews.

Data Analysis

Analysis of the data was based on a grounded theory approach (Strauss & Corbin, 1990). Data was be presented in a descriptive manner in order to develop the cultural context and analyze the sociocultural interactions of the participants. However, the goal was not to summarize these viewpoints. Instead, grounded theory was utilized in order to conceptualize the important aspects of the case to allow the researcher to focus on the emerging theory. Strauss and Corbin describe grounded theory as a "transactional system" that "allows one to examine the interactive nature of events" (p. 159). Data analysis involved several stages of sifting through data and coding concepts into categories in an effort to narrow focus of inquiry, first through open coding and narrowing to more selective coding of the categories (Strauss & Corbin). This allowed an image of the culture of science education to emerge directly from the data. This process involved a constant comparative method in which categories of data are continually analyzed and compared throughout. The use of various methods and data sources provided multiple perspectives on the culture of science education. As categories developed, each source was reviewed to see if similar themes began to emerge. Glaser and Strauss (1967) explains that the constant comparative process in grounded theory is a "continuously growing process" that continues until the analysis is complete (p. 105).

Research Limitations

This study was an ethnographic case study that focuses on the context of a small rural school. Through the use of thick description, the researcher will provide enough crucial information for readers to determine if this case has implications for other studies (Geertz, 1973). However, it was understood that all observations, interviews, field notes and results are representative of a single case. Galison (1997) warns of the consequences stemming from case study research aimed at generalization and representation. He suggests to the readers of *Image and Logic* that the historical accounts within be viewed not as cases, but "as parables that work by evoking particular epochs of experimentation rather than as cases that work by being representative" (p. 62-63). The science teachers in this case study were unique. Their individual histories and experiences coalesce into a community of teachers like no other, so it would not be appropriate to generalize this case as being representative of other cases across the southeastern United States. Stake (1995) suggests that cases are not typically chosen with the primary goal of understanding other cases. Instead of an attempt to generalize with other cases, my efforts focused on understanding the particularities of this case. Although this case was not representative of most, others may learn from the stories that these teachers share, and hopefully, each reader will experience something that will be personally useful. Galison and Stump (1996) refute the ideals of scientific realist who use case studies in the history of science as proof for accepting theoretical entities, referring to this effort as a "hopeless strategy" (p. 358). This study was not intended as proof. Instead, it was the beginning of a conversation about the culture of science education that will hopefully lead, not so much to answers, but to further investigations that provide deeper insight into the world of the science teacher.

A second limitation of this study was the amount of time spent in the school. Although the researcher conducted the research throughout the semester and maintains the option to return for questions and clarifications, the researcher was a full-time instructor and can only be present at the site in the mornings until noon. This allowed the instructor to be present when the teachers arrived at school and experience morning duties, homeroom class, planning period, and one ninety minute class each day. On some days, the researcher was able to stay through lunch which was a valuable time to observe the teachers together as a group in a more relaxed setting. The researcher countered this limitation by frequent visits over an extended period of time. This enabled the researcher to spend more time with the group in order to build trust and help them to be comfortable with the researcher's presence (Lincoln & Guba, 1985).

Research Delimitations

The goal of this study was to describe the culture of science education and how this culture influences teacher practice. It was presented through the perspectives of the science teacher participants as they provided their own stories and opened the doors to their classroom for the researcher to observe their day-to-day life. Participation in this study was delimited to science teachers in a small rural high school. This study aimed to describe the culture of science education and was not intended to evaluate effectiveness of teacher practice, nor did it seek to identify appropriate use of pedagogical strategies. Students in the classroom were not the focus of study. However, the teachers' interactions with those students, including but not limited to their classroom teaching was a contributing aspect of this study. Students were not interviewed or directly observed by the researcher. It was possible that this study potentially utilize records provided by teachers that relate to general performance on standardized tests. However, these scores were not used to evaluate teachers' effectiveness on student learning. Instead, such records were analyzed as artifacts within the culture of science education. The study focused on a single case and will not seek to compare the teachers in this case with other science teachers.

Research Integrity

The researcher remained cognizant of possible bias, and continuously monitored internal validity and external validity to ensure that the study is trustworthy and valuable (Lincoln & Guba, 1985). Through experience as a high school science teacher and as a science methods instructor, the researcher made choices regarding pedagogy and practice without always being conscious of the impact culture plays on these decisions. Erickson (1984) explains that when making decisions, the researcher must practice "*disciplined subjectivity*" to avoid bias, making a conscious choice not to be swayed by emotions that might emerge during the study. Being aware of this, the researcher took care not to overlook cultural influences or other factors that potentially cause participants to make choices regarding similar issues. In a naturalistic inquiry, Lincoln and Guba suggest criteria for ensuring that the study is trustworthy. These include credibility, transferability, dependability, and confirmability. Specific techniques are utilized by qualitative researchers in the field to ensure the credibility of research findings: prolonged engagement, persistent observation, and triangulation (Lincoln & Guba, 1985). Prior to the first observation, participants were fully informed of the intent of the research and the research process. They were assured of anonymity throughout the process, and were asked to sign a letter of consent agreeing to participate. First of all, the researcher developed familiarity with the participants and the site through prolonged engagement in an effort to reduce the stigma of being an outsider. By spending time at the site and interacting with the participants on a daily basis, the researcher did seem like a threat. This allowed the teachers to become comfortable with the researcher's presence in their classrooms and in their intimate conversations with colleagues. The researcher maintained focus on the relevant issues through persistent observation. Lincoln and Guba describe persistent observation as a way of "sorting out irrelevancies" in order to recognize important aspects of the culture (p. 304). Emerging categories that stand out as important to the study received more focused inquiry, while those that seem insignificant or irrelevant were sorted out. This enabled the researcher to provide greater detail and explanation of the more important aspects of the culture.

Triangulation of data was accomplished through the use of multiple methods. Methods used in this study include participant observation, open-ended interviews, and focus group interview. Observations and interviews will be conducted with each participant, providing multiple perspectives on the culture of science education. In addition to providing credibility to the research, the use of multiple methods and sources added to the dependability of the study. Also, documents provided by teachers in the way of meeting minutes, letters or memos from the school or district, and lesson plans were utilized as a source to verify issues discussed during interviews and observations. According to Lincoln and Guba (1985) external validity cannot be specified in a naturalistic study. Instead, the researcher must provide a "think description" that will allow individuals to determine if the findings are transferable to their own situation. Geertz (1973) describes culture as being "a context, something within which [social events, behaviors, institutions, or processes] can be intelligibly—that is, thickly—described" (p. 14). Through a thorough description of the culture and interactions within the culture, transferability was determined.

Summary

The purpose of this study was to define the culture of science education and examine the impact this culture has on teacher choice in the science classroom. This study used multiple theoretical perspectives, providing a conceptual framework with both an ethnographic (Geertz, 1973; Goodenough, 1970; Merriam, 1990; Spradley, 1980) lens and a social constructivist (Lave & Wenger, 1991; Vygotsky, 1978; Wertsch, 1985) lens that allowed for better understanding of the culture. A qualitative research design was conducted in the tradition of case study (Merriam, 1990; Stake, 1995; Denzin & Lincoln, 2003) that allows the researcher to observe, interview, and document the sociocultural interactions within the context of the community of practice (Geertz; Lave & Wenger, 1991; Lincoln & Guba, 1985). The study was conducted in three overlapping phases that allowed time for the participants to become comfortable (Lincoln & Guba) with the researcher's presence in the school setting and allowed the researcher to develop and implement a plan for interviews and observations (Patton, 1990; Spradley). Qualitative data analysis methods consistent with grounded theory development (Glaser & Strauss, 1967; Merriam; Strauss & Corbin, 1997) were used to construct an understanding of how the culture of science education influences teacher practice. The researcher used the constant comparative method (Glaser & Strauss) to evaluate data and allow relationships and patterns to emerge directly from the data.

CHAPTER FOUR: ANALYSIS OF DATA

The purpose of this study was to gain an understanding of the culture of science education in the context of a small rural high school. More specifically, this study investigated how this culture informs teacher practice in the science classroom. This study recognized that science teachers are members of a community of practice (Lave & Wenger, 1991) from which teachers work to negotiate meaning and establish themselves as acceptable, functional members of the community. An ethnographic perspective ((Denzin & Lincoln, 2003; Geertz, 1973; Goodenough, 1970, 1981; Lincoln & Guba, 1985; Merriam, 1990; Stake, 1995) was used as a lens for understanding sociocultural interactions and other cultural influences that informed the group. A social constructivist (Lave & Wenger, 1999; Vygotsky, 1978; Wertsch, 1985) lens enabled the researcher to view learning as social process by investigating participants' interactions with one another, other teachers and administrators within the school setting, and the interactions with students. These perspectives enabled the researcher to understand and explain what informs teacher practice within the context of the day-to-day activities involved in teaching science to secondary students and the social interactions that occur within this community of practice (Lave & Wenger, 1991). The research was guided by the following questions:

1. What defines the culture of science education?
2. How does the culture of science education inform teacher practice?

Data collection and analysis were accomplished through the use of multiple data procedures. These procedures included (1) observations, (2) interviews, (3) informal conversations, (4) focus group interviews, (5) field notes and reflections, (6) audio recordings, and (7) documents, such as meeting minutes, lesson plans, and school correspondence were collected for analysis.

In order to define the culture of science education and to understand how this culture informs teacher practice, it was necessary to understand the sociocultural interactions that occurred within their community of practice (Lave & Wenger, 1991). The researcher used a grounded theory (Strauss & Corbin, 1990) approach to analyze the data, allowing themes and patterns to emerge directly from the data. Constant comparisons (Strauss & Corbin) were made to ensure consistency across multiple data sources as the themes developed.

First, this chapter provides an explanation of data analysis that led to the emergence of patterns and themes within the study. This is followed by a discussion of the five themes that emerged from the analysis of data: (1) *constant collaboration*, (2) *teacher identity,* (3) *mandated policies,* (4) *instructional method* and (5) *laboratory work*. Results are organized into two sections based on the research question being addressed. Within the results, themes are supported by the domains that substantiate the consistency of the theme throughout data sources. The first result section addresses the themes of constant collaboration, teacher identity, and mandated policies emerged to help define the culture of science education. The second results section addresses how the culture of science education informs teacher practice through the themes of instructional method and laboratory work. Throughout the discussion of each research question, the researcher uses examples of data to support the findings. Excerpts from conversations, interviews, and field notes were chosen that were representative of events and patterns across the study.

Data Analysis Phase

Merriam (1990) describes data analysis as "the process of making sense out of one's data" (p. 127). In the tradition of case study, the data analysis is organized into conceptual categories based on an intuitive and systematic process (Merriam). Inductive coding was used to organize the data and develop themes that help present concepts that emerged directly from the data (Strauss & Corbin, 1990). Each phase of data analysis focused on understanding the sociocultural interactions to describe the culture of science education and how this culture informs teacher practice. The data analysis phases were divided three coding types: (1) open coding, (2) axial coding, and (3) selective coding (Strauss & Corbin). Each level of inductive coding enabled the researcher to refine and revise themes and categories that represent concepts evidenced in the data. The processes associated with grounded theory analysis are designed to enhance precision and rigor while incorporating the element of creativity (Strauss & Corbin).

The process of *open coding* began when the first data were collected (Strauss & Corbin, 1990). This continual process required that the researcher read field notes and transcripts, line-by-line to better understand what was occurring in each situation. Key terms and phrases were highlighted and noted in the margins. Throughout this phase of the coding process, the researcher utilized the constant comparative method (Glaser & Strauss, 1967; Merriam, 1990; Strauss & Corbin) to ensure that categories hold consistently throughout the data and lead to categories that are both descriptive and explanatory (Lincoln & Guba, 1985). Open coding required that the data be broken down and conceptualized through the analysis of discrete incidents. As categories began to emerge from the codes, the researcher continually questioned what was going on in the data and how it related to the research questions (Strauss & Corbin). Transcripts and field notes were read and reread constantly throughout the coding process as categories were analyzed and developed based on properties and dimensions. This process allowed codes and categories to emerge directly from the data (Strauss & Corbin).

Once categories were established, the process of *axial coding* was used to make connections within the data and link categories with subcategories (Strauss & Corbin, 1990). The paradigm model (Strauss & Corbin) was used to help the researcher think systematically about the data and to ensure density and precision of the study. In this model, the data was linked using a set of relationships that aided in developing depth of understanding for each category and in providing a framework for comparing various incidents within the data. Continuing with the use of the constant comparative method (Glaser & Strauss, 1967; Merriam, 1990; Strauss & Corbin), the researcher looked for relationships between the data and the emerging categories. At this point, data analysis became more purposeful. In other words, the researcher actively sought instances that held true to the emerging themes (Strauss & Corbin). Five themes emerged that ground the study’s focus on the sociocultural interactions of science teachers as part of a community of practice (Lave & Wenger, 1990). These are identified in Table 4.1.

Table 4.1

Five Research Themes

Interactions	Themes
CI-PR	Constant Collaboration
PR-ST	Teacher Identity
CI-PR-ST	Mandated Policies
PR-ST	Instruction Method
PR-ST	Laboratory Work

*Note: * The following codes were used denote the type of interaction: CI=collaborative interactions, PR=personal reflections, ST=science teaching*

The final stage of data analysis involved the use of *selective coding* to validate relationships and to refine and develop categories (Strauss & Corbin, 1990). In this process, categories were grouped together through questioning data and the use of constant comparisons to relate categories based on their conditions, context, strategies, and consequences (Strauss & Corbin). Once categories were developed, they were merged into core categories that supported the development of the five overarching themes that emerged from the data to answer the two research questions.

For the purpose of Chapter Four, the following two sections are an account of the findings to the research questions based on qualitative data analysis. Each section includes selected data accounts that illustrate the findings that were representative of the research questions. Therefore, a list of codes was created by the researcher to specify the original source of data for each excerpt. The codes provide connection between the analysis and the data sources from which the themes emerged (see Table 4.2).

Table 4.2

Codes by Data Source and Description

Code	Description
FN, PN	Field notes by page number
FG, PN	Focus group interview transcript by page number
I, PN	Interview transcripts by page number
D, PN	Documents by page number

Note: Transcript, field notes, and document codes are recorded in the narrative findings to indicate the specific data source.

Result: Defining the Culture of Science Education

In response to the first research question, data analysis consistently found that defining the culture of science education involved three themes: *constant collaboration*, *teacher identity*, and *mandated policies*. Each theme is supported by the categories that sustained the emergence of the theme and evidenced by excerpts from the data that exemplify the views and interactions of the community. The theme of *constant collaboration* emerged from two core categories of collaboration, forced and unforced, that occurred throughout the study. These categories held constant through field notes, individual interviews, and focus group interviews. Then, a follow-up interview provided evidence of a transformation of collaborative efforts from unforced to forced, as new policies were developed for the school. The second theme, *teacher identity*, began to emerge during the first few weeks of observations and became stronger through data analysis as the theme developed. During individual interviews, codes that developed from the initial analysis of field notes taken during observations were later solidified when compared to personal accounts provided by teachers during one-on-one interviews. Finally, the theme of *mandated policies* draws from each of the previous themes and highlights the impacts of national, state, district, and school policies that affect the day-to-day routines and interactions of the participants.

Constant Collaboration

Data analysis consistently supported the theme of constant collaboration among the science teachers within the community of practice (Lave & Wenger, 1991). Throughout the school day, science teachers were communicating with one another for a variety of reasons including science content, pedagogy, classroom management, and student behavior and performance, among other issues. Moments of collaboration within the community appeared in both formal and informal ways, but they were always supportive in nature. The importance of teachers' collaboration and working together within a community is well-documented (Hargreaves, 2003; Wineburge & Grossman, 1998; Shulman & Sherin, 2004). The teachers sought out one another for advice, expertise, and camaraderie. There was a sense of collegiality among the teachers. When asked to share about their relationship with others in the department, they did so with a positive tone. The constant collaborative nature of the group was characterized by respect and trust for one another's knowledge and abilities, an assurance that shared concerns would be held confidential, and a sense of confidence in the dependability of colleagues.

For purposes of this study, two domains emerged to support the theme of collaboration: *forced collaboration* and *unforced collaboration*. Forced collaboration involved that which is mandated by the school to ensure that teachers communicate about important issues. Unforced collaboration involved self-regulated communication between and among teachers when they deemed necessary. The term forced was not intended as a negative connotation, simply that the teachers were not given a choice about the time, format, or purpose of the meetings.

Forced collaboration. All departments at Braxton High School were required to have one professional learning community (PLC) meeting each week. All science teachers had a common planning time in the morning, and every Wednesday was reserved for PLC. These meetings were very structured, with a specific agenda established by the school administrative team. The required agenda included: call to order, reading of the norms, curriculum, instruction, assessment, and items for next week [D, 5-7]. Meeting minutes reflected the adherence to these requirements, and field notes and interviews provided a between-the-lines view of what occurred during these meetings.

The meeting agenda dictated all official activities of the PLC requiring that the spaces be filled with specific items pertaining to curriculum, instruction, and assessment. For curriculum, they discussed a range of issues. Most often, this segment was used by Ruth to relay messages from the lead learner meetings, a meeting of lead teachers from each department in which the superintendent and/or principal presents new regulations or initiatives for the school and/or district. At other times, they discussed equipment needs for the classroom, planning for standardized test review, and other upcoming events [FN, 105, 115, 155, 173, 197, 283, 289]. The segment on instruction involved each teacher providing a quick overview of what they would be doing in the upcoming week. Sharing of instruction was typically short, including only the topic to be covered along with specific laboratory activities or special materials, videos, or books that would be used. For assessment, one teacher would bring a summative assessment that he or she was giving in class, and everyone would analyze the test to determine what percentage of the test were critical thinking questions. Discussion of test analysis was typically limited to numerical percentages that were recorded in the minutes to verify completion of the task.

Precaution was taken to ensure that all agenda items were incorporated in the minutes. At the end of each meeting, Emma, who served as PLC secretary, read through the minutes she had recorded to confirm that others were in agreement. When an agenda item was not well defined, she would ask what to include. For example, one meeting began late because the teachers were involved in conversations about classroom management and other issues with students. When the formal meeting began, time was running short, so they started with a brief discussion of instruction for the upcoming week and then, went straight into analyzing one of Emma’s tests for the assessment section. Near the end of the meeting, Emma asked, “Under curriculum, what do you want me to put?” So, Ruth recalled a comment from the lead learner meeting that was not a pressing issue, but would show that they had addressed something for curriculum on the agenda. This didn't seem like enough, so after a few moments, Emma shared a questioning technique that she had observed in a language arts classroom [FN, 155]. When all were satisfied that the meeting minutes would reflect a completed agenda, the meeting was adjourned.

The following segment from a focus group interview, presents a collective view of PLC meetings and the required format. The dialogue illuminates the frustration and sense of powerlessness associated with forced collaboration.

Emma: Well, we have certain agenda items that we have to follow. Like, we have to address curriculum, instruction, and assessment every time. And I wish that we didn't quite do that. Sometimes, we don't know what to put under what category. Like under instruction, I put lesson plan for the next week because, I don't know. Under assessment somebody brought a test or whatever, I put that under there, but what if it was a time when we weren't suppose to be doing that. Like we have had times where they've told us not to do that, that we had another focus for the meeting, so I mean, what do you put under that if you're not supposed to be addressing that? I don't know. Under curriculum a lot of times, we'll put stuff like whatever Ruth is telling us on the lead learner meeting, and that doesn't necessarily have to do with curriculum. But I put it up under there because I don't know where else to put it.

Ruth: Right. And then we bring student work sometimes and look at that.

Emma: Yes.

Christy: And we're supposed to read the norms.

Emma: We're supposed to read the norms every time. We're supposed to call to order. I mean, it's supposed…yeah…we're supposed to do that. I mean, it's on our agenda items.

Ruth: It's too restrictive.

Emma: Yeah. And we have to …I have to leave this in place. I don't ever change it. We have to have a facilitator, a person who reads the norms, and a time keeper. We have to have role assignments. We have to put whose present and who is visiting.

Christy: It's almost like we're being punished because other groups don't do what they're supposed to. With something like this, you force everybody to do what they've asked to do.

Emma: You know when we first started doing PLC…nobody else was doing it. We were doing it because we wanted to do it, because we had a goal in mind. We had things we wanted to discuss and that seemed very relevant.

Ruth: Yeah, during the PRISM years.

Emma: That was… we had things that we wanted to accomplish and that's why… but now, there's things we have to discuss that are kind of…we're kind of restricted on what we can do, but sometimes we slip it in anyway.

[FG, 71-72]

The frustration was evident in their tone and was consistently apparent in instances in which they were asked about the PLC. The researcher noted at each PLC meeting, however, that they did "slip it in." Discussions that occurred as teachers were entering the PLC meeting room, Emma's classroom, were focused on immanent issues of classroom management, content needs, and general planning. During one meeting, as the teachers were analyzing one of Dale's tests for the assessment segment, he and Christy were having a conversation about using stem cells to grow a urethra [FN, 289]. He was very excited about the possibility of using this current event in his biology class and wanted to share it with her. The topic sparked a conversation about content and science misconceptions. In response, Emma described an episode of the television show Grey's Anatomy where they used stem cells in a medical procedure. She said, "I didn't know if that was a real thing or a TV thing" [FN, 289]. Emma did not record this conversation or many others like it in the meeting minutes because the conversations were not directed to a specific agenda item. Yet, most conversations that occurred between the lines of the meeting minutes were purposeful and productive, focusing on issues that directly impact the teachers.

During individual interviews and focus group interviews, the teachers shared their views regarding the collaboration that occurred during the PLC meetings and how the meetings had changed over the years. Such conversations were also noted in field notes as teachers shared their concerns with the researcher individually. Emma pointed out that the science department started having PLC meetings before it become popular and long before it became mandatory for all departments in the school. She referred to a time when the science department worked closely with the local university to develop collaborative partnerships with university faculty. This was part of an initiative by the National Science Foundation's Partnership for Reform in Science and Mathematics (NSF-PRISM, or PRISM). Emma said, "PRISM helped me a whole lot. I sure do miss the camaraderie and the conversation that went on during that time…before anybody thought I wasn't doing a good job, I suppose… I felt like those kinds of relationships, partnerships that were formed were invaluable to me" [I, 37]. When referring to these partnerships, Ruth described PRISM as the "golden years" for PLC [FN, 130, 149]. During this time, PLCs were focused on the immediate needs of the community. The teachers were able to work on things that they needed to get done or focus on issues that were of importance to the department, such as the implementation of technology. Now, Ruth explains, "The form dictates the function," going on to say that the PLC meetings forced by the administration were counterproductive [FN, 150]. Instead of being supportive of the needs of the teachers, the meetings tear them away from the things that they need to do.

Unforced collaboration. Communication among participants occurred throughout each school day. This was observed and noted by the researcher throughout the field notes, and participants often spoke of the frequency with which they collaborated with others in the science department. Ruth noted that "There's just a lot of contact throughout the day… As needed there is a lot of communication. As things come up, it helps to be in the same general pod (referring to location of classrooms)" [I,18]. While observing the interactions of the participants, it became evident that communication almost always had purpose. Superficially, many interactions seemed to be no more than an excuse for adult conversation, but after close and continuous observation, it was obvious that more was going on in the day-to-day conversations than just small talk. During a focus group interview, the teachers spoke candidly about their daily encounters.

Emma: Well, we're required to meet every week, once a week, but now, God knows we talk every day. Dale and I have breakfast duty every morning together, so we get to see… like last semester when he and I had to twin for physical science, we got to plan out everything during breakfast so that we didn't have to spend so much time during first period trying to plan, you know. And we'd talk every day.

Christy: We eat lunch together. Everybody but Dale, he has second lunch.

Emma: Right, the three of us get a lot done during lunch time.

Ruth: And we talk a lot in the hall.

Emma: Yeah, we talk a lot in the hall. Or they do. I don't feel comfortable leaving mine. I just stand at the door.

Christy: I come out second and third. I don't come out fourth. (She laughs to indicate that she does not want the students out of her sight.)

Dale: I just have a little bit more walking to do. (His classroom is the only room located outside of the science area.) I don't walk up here between classes, but I probably see Christy every day during first block at some point in time. If a question comes up or something, I just walk down.

[I, 65-66]

Unforced collaboration occurred naturally and without coercion from the school administration. This form of collaboration seemed to be dictated solely by time, space, and necessity. This type of collaboration occurred in the third space, referring to the spaces in-between the classrooms where conversations occur (Moje, Ciechanowski, Dramer, Ellis, Carrillo, & Collazo, 2004). Examples of third space represented throughout data analysis include the hallway, classrooms when class was not in session, the library copy room, and the cafeteria, among others. Dale's classroom was located on a hallway on the opposite side of the school, a two or three minute walk depending on how many students were in the hallway. Despite this arrangement and the fact that his lunch break fell at a different time than the other science teachers, he managed to communicate with them on a daily basis. As Emma indicated, the two were able to transform their breakfast duty into collaboration and planning time when they twinned for physical science. The term "twin" was used to refer to two teachers who taught the same content course. In the previous semester, Emma and Dale twinned for physical science. During the semester in which most data were collected, Dale and Christy twinned for biology. Because they did not share the same duty time/space, the two made the effort to communicate during their planning period.

Collaboration between Dale and Christy was observed at multiple incidents during the study. Because they were both teaching biology during the semester, they made extra effort to work together. Although every incident was not noted, Dale was observed frequently in route to or from Christy's classroom or they were noted as standing together chatting in the hallway. During the individual interviews, two brief encounters were noted. The following narrative was captured during Christy's formal interview. Although the researcher encouraged them to proceed if needed, Dale kept the conversation brief so as not to disrupt the interview.

Dale: We're not putting 10-1 on this test, right?

Christy: No.

Dale: Did you want, like the phases, or are you just going to give it to them and just kind of briefly…

Christy: I cut out some of my notes on the phases.

Dale: None of that is going to be on the test?

Christy: Not much, but I'm going to make them do the cell cycle foldable today, just to draw the phases and see.

[I, 24]

After a short pause, Dale apologized for the interruption and quickly left the room. A similar incident occurred when conducting Dale's formal interview. Christy stopped by to discuss an upcoming laboratory activity that involved the use of microscopes and to share a lab sheet that was to be included in the biology lessons for the week. They were making preparations to switch classrooms since Dale's classroom was not equipped for laboratory work. After confirming the arrangements and discussing plans for the lab, the two of them proceeded to share observations regarding their students' laboratory experience prior to high school.

Dale: I asked [the students] the other day, and some of them had never used a microscope.

Christy: I don't think they have any at the middle school. If they do, they don't have that many.

Dale: A couple of mine have, but some of them said that they had never seen one at all. That surprised me because I figured, you know, in life science they would do that.

Christy: I haven't seen where any of them have. They get excited that they get to touch one. And, I got jeopardy set up for you…

[I, 55]

The conversation continued as they negotiated how to setup computers and presentation devices so that the rooms would be ready for use by the other teacher. In less than five minutes, the two were able to coordinate activities, share concerns about student preparation for laboratory work, and negotiate technology needs for the classroom switch. When Christy left the room, Dale expressed that they communicate everyday to keep track of what the other is doing and to maintain consistency across the classes.

Dale: It's not like somebody is just doing whatever they want to do. You know, somebody else is doing what you're doing. It just maybe gives you more confidence that you're doing what needs to be done. And, also for the kids, it gives them confidence. You know, you click with some kids and you're not going to click with other kids, and you got one kid who says, 'Ah, I can't stand Coach

Dale. Listen to what he made us do, and they go, well Mrs. Christy made me do that today, too. So, when you hear that, you know for the kids, I think there's… we're doing the same thing, and then you get kids that have to transfer…I talked about that kid that went from regular to honors, it's the exact same plans. So, you know, it's no different for them.

[I, 60]

Short episodes such as these were observed on a daily basis. Each appeared to be voluntary and with a collaborative purpose.

Even when teachers were not teaching the same content course, there were many incidents of collaboration about topics such as pedagogy, classroom management, and content. Emma summarized the collaborative nature that was characteristic of everyone in the group both in areas of content and in other duties and responsibilities required of the department.

Emma: I tell you we work well together. There isn't a single thing that we're told that we have to work on or that we want to work on together that we don't all buy into. I mean, we normally are in agreement on whatever it is that needs to be done. That is, we don't argue, fuss, fight, but I tell you something else, too. We recognize that everybody has their strengths, and we defer to those who have that strength. I know that I don't know biology. I'm going to defer to Christy and Dale to whatever it is that they say. I'm not going to sit there and argue with them because they know more than I do. By the same token, they're not going to argue with me about physical science because I know more than they do. We're not going to argue with Ruth about chemistry because we know she knows more than we do. You know, I have confidence in these people. I've seen them teach. I know that they're good at what they do, and if they say it's something that needs to be done; then it must be something that needs to be done, needs to be taught, or whatever.

[I, 50]

Whenever questions would arise in a specific content area, others were not afraid to seek help and trust their colleagues to be supportive and knowledgeable. Data analysis consistently evidenced the need for this form of unforced collaboration across data sources, appearing in individual interviews, focus group interviews, and field notes. In a focus group interview, the following exerts provide evidence of the respect and trust shared within the department:

Ruth: That's it. And there's a lot of mutual trust also. You don't feel like if you say something, somebody's going to run, tell somebody. You feel like you can tell anything in front of anybody. (Others respond in agreement.)

Emma: A lot of faith in everybody else's ability, too. (Others respond in agreement.)

Ruth: Respect and value for each person's knowledge base and skill set.

Emma: That's right. Everybody has strengths. And everybody recognizes those strengths in each other.

[FG, 64]

Several instances appeared in the field notes of consultations regarding science content. One exert was of particular interest. Ruth was taking medications to prevent another outbreak of shingles, and it was delaying her reaction time and affecting her ability to concentrate [FN, 153]. Before giving a physics review question to her class, she explained that it was necessary for her to consult with Emma about the proper calculations. This was a concept that Ruth knew well, but due to medication was unable to perform the task at that moment. She showed no reservation about seeking help from a colleague to ensure accuracy when using the question in class. She said, “My brain just took a vacation again” [FN, 150]. Ruth felt that she could refer to Emma for help with no fear of ridicule. During the focus group interview [FG, 73], she briefly mentioned a time when she consulted with Emma on a physics equation that a student included in a paper. She was unfamiliar with the formula, and consulted with Emma to ensure that it was correct. Emma explained, “It was a made-up-one, too, wasn't it?” and laughed. The following exert is from a focus group interview where Emma describes an example of how she consults with Ruth when teaching certain chemistry topics:

Emma: I do not do orbital notation in the 9th grade, but my pre-AP kids especially need to know that once you get past Argon, you go to Potassium; it doesn't fill the same way. I mean, you know, the rules don't apply the same way, so I have to get instruction from Ruth every time I tell them because I never remember. And so, I have to always go back to her and ask what to tell them. [I, 68]

During the focus group, each teacher expressed the importance of working together and getting along with one another.

Analysis of the theme revealed that constant collaboration was a major component of the culture of science education. Both forced and unforced collaboration provided an avenue for teachers to share ideas and support the needs of one another. The forced collaboration was seen as scripted, leaving little time to discuss issues that directly impacted their classroom [I, 39]. Emma explained that this was time that would be better suited to "share and solve problems within your department… not a time for somebody else to tell you exactly how it's all suppose to go" [I, 39]. Despite these concerns, the researcher noted that times of forced collaboration often resulted in productive communication between-the-lines of the restrictive meeting agenda. Discussions regarding classroom management, content, pedagogy, and many other issues that the teachers considered important were addressed informally during the PLC. However, these conversations were never recorded in the meeting minutes. Unforced collaboration occurred voluntarily throughout each school day. Teachers met as needed to plan for classes, address questions of content, discuss classroom management and individual student needs, and to attend to other issues of direct need for their classes. Whenever two teachers shared a common content class, they made a special effort to ensure that the courses were consistent and provided students with similar experiences. The collaboration of this community of practice was best summarized in an excerpt from Ruth's one-on-one interview:

Ruth: It’s like different parts of a machine that functions well. Everybody volunteers when extra work is needed. It’s just very supportive, very cordial relationship like a family, members of a family. There’s no competition or back biting or anything like that. It truly is like when the tide rises all the ships float. We all help each other and our students do well.

[I, 8]

During a follow-up conversation that occurred during pre-planning of the next school year, Emma and Ruth informed the researcher that there was a new school policy to ensure that all classes were consistent. Whenever two teachers taught the same course, they were required to develop a “twinning notebook.” They explained that teachers sharing a common course must provide evidence that the students in each class would learn the same content and be able to experience the same learning activities. In addition, those who twinned were required to have formal meetings during their common planning periods [FN, 308]. Therefore, a form of collaboration shown consistently in data analysis as being unforced was transformed into a form of forced collaboration, mandated by the school’s administration. Planning that once occurred voluntarily and at the discretion of the science teachers, was now being forced, with restrictions that designated the time and space where the meetings occurred to ensure that all departments followed the new policy.

Teacher Identity

Throughout data analysis, the findings showed teacher identity to be a consistently prevalent theme necessary in defining the culture of science education. Through extensive collaboration, the science teachers in this community of practice made strong efforts to maintain consistency in their classes, particularly if they were teaching the same content. Lesson plans were identical for those who were teaching common courses. They used identical PowerPoint presentations and handouts, gave the same laboratory activities, homework, and summative tests.

Even if they were not teaching the same content, the teachers all maintained a similar lesson structure and teaching style, but each maintained a unique personality that was not paralleled by other members of the community. Although they sought to maintain consistency, there was a difference between the teachers that took time to emerge within the data. What emerged from observations, field notes, and individual interviews was the theme of individual teacher identity. Gee (2001) describes a person's identity as the "kind of person" someone is recognized as being within a given context. He states that "all people have multiple identities connected not to their 'internal states' but to their performances in society" (p. 99). The identity of each participant was evidenced, not only by teaching style and pedagogical strategies, but also in his or her approach to teaching and interactions with the students.

The strength of this theme was grounded in the teachers' own stories of how they came to be a science teacher and in the presentation of their lessons. Wenger (1998) explains that the formation of identity is a property of social communities that involves a dual process of identification and negotiability. The process of identification allows a person to determine which meanings matter, while negotiability involves making those meanings applicable to new circumstances (Wenger). Identification incorporates experiences and associations, both positive and negative, that shape and mold an individual into the person he/she labels him/herself as being within a given community. This part of the process was used to understand how the science teachers developed their views of what it means to be a good teacher. Negotiability involves the application of meaning in order to become a functioning and accepted member in a community of practice (Wenger). This part was used when considering how each participant's story translated into the observed teacher identity exhibited in the classroom. Examples from the research are discussed and supported by a comparison both across data sources and across participants. The theme of identity involved more than simply teaching style and utilizing the same methods with which they were taught. Characteristics and behaviors discussed in their stories of former instructors, career experiences, and other activities on the path to becoming a science teacher contributed to the formation of each participant's unique identity as a science teacher. The following evidence from the data was organized with a full discussion *identity formation and negotiation* for one participant. This is followed by a comparison *across the community* to evidence similar phenomena occurring within data accounts that involved each of the other three participants.

Identity formation and negotiation. Data analysis revealed that Ruth's teaching consistently reflected a caring and nurturing relationship that the researcher noted as being similar to that of a mentor and her apprentice. The researcher noted that Ruth "treats each student as if he/she is a professional; speaks to them as if to explain something to an apprentice who is eager to learn" [FN, 141]. Ruth was able to emulate the experience of a one-on-one discussion by centralizing focus on the individual student to whom she was speaking and tune out other conversations and interactions in the classroom while still maintaining control of the class. The mentor-apprentice persona was carried throughout all interactions with her students. Her comments were always very encouraging. While her teaching style could be described as primarily direct instruction and supplemental laboratory work, each lesson was filled with opportunities for guided practice that allowed her to devote more time to individual students. Careful analysis of field notes showed that Ruth did not spend a lot of time at the front of the classroom. She was always walking around the room, speaking to students one-on-one and continually praising students when they did well [FN, 145]. Ruth was very meticulous with her use of scientific language and ensuring that students employ correct terminology in their explanations and questions [FN, 144]. This characteristic was also evident as she ensured that students were following instructions for both guided practice and laboratory work [FN, 144, 145]. Ruth composed herself as an intellectual, poised and confident. She approached her content with a fervent attitude that did not question her students' desire to learn. As she neared the end of a lesson on dimensional analysis, she commented to her students, "Let it flow over you and embrace factor cancellation. Love it!" [FN, 145]. She was not unaware of those who were distracted or apathetic regarding the lesson, but she behaved as if everyone shared in the challenge of learning and made extensive effort to include those who were in greatest need of the one-on-one attention.

Analysis of personal reflections given during interview sessions revealed that Ruth developed strong convictions about science teaching from her former educators. When discussing her high school science teachers and college professors, she described them as excellent to very good, citing specific examples of strategies that worked well in their classes: direct instruction, a lot of labs, and guided practice. She explained how her major professor "opened the world of independent research" for her as a college freshman, showing her "how a professional scientist really operates" [I, 4]. She described these teachers and professors as "very nurturing; they get to know their students very well. They spend a lot of time talking to their students" [I, 4]. It was this nurturing and caring way of engaging with her students that characterized Ruth's identity in the classroom. In addition to those inspirational educators, Ruth also described negative interactions that exemplified behaviors she wished to avoid, stating that "every now and then, however, I would run into one who was totally incomprehensible" [I, 2]. She explained how these professors would have no A's and maybe only a few students with a low B. The following excerpts are from her one-on-one interview that occurred after the researcher had observed her teaching:

Ruth: I always wondered how as a teacher that would work. I mean, I've always thought that if you're presenting your class effectively and you have strong motivated students… that if you can't have somebody that's making an A, then you need to reexamine your course.

[I, 2]

The negative experiences associated with these professors helped her to realize the type of teacher she did not wish to be. She went on to describe characteristics that she identified with being a good teacher.

Ruth: So, to me, it is a failing if your students do not succeed, given that they are very capable, motivated students. And, you don't want to turn them off. So, you don't want to water it down. You don't want to make it easy. You have to be demanding, but I think if you are going to be demanding, you have to give them the help they need to meet those demands. It's similar to the old master and journeyman and apprentice system. You have to nurture them and hope that they will achieve more than you do one day.

[I, 3]

This statement affirmed the comment previously noted by the researcher that Ruth demonstrated a mentor-apprentice relationship with her students. Ruth applied these characteristics to her own interactions with students and, as much as possible, provided students with a nurturing and caring classroom environment with high expectations for success even when more than a few students were not as motivated as she would like. The master and apprentice system was noted previously in the field notes and further evidenced as part of Ruth's teacher identity when she used that specific example to describe, in her own words, what it meant to be a good teacher. Because science teaching was Ruth's third career path, she had the experience of participating in several different communities of practice (Lave & Wenger, 1991). Her ten years working in the field of journalism also made its mark on her identity formation. Her meticulous nature noted by the researcher was, in part, derived from her experiences as an editor. She explained that “editing is picky, and so it’s a habit of mind that transfers into science, that pickiness” [I, 5]. During an informal discussion regarding career choices, she stated, “We find our niche that fits our personality” [FN, 167]. Extending on that concept, the formation of teacher identity refines our personality to fulfill that niche.

Comparison across the community. When comparing these findings to that of the other teachers, a consistent pattern emerged to support the idea that the formation of teacher identity was rooted in the individual’s participation in various communities of practice (Lave & Wenger, 1991). Communities and experiences varied from one teacher to the next, but stories shared during one-on-one interviews and information conversations documented in the field notes consistently supported that participation in these communities of practice contributed to the formation of teacher identity. Meanings that came to matter to each teacher were negotiated within and become part of the teacher that they were in front of the class. This segment was divided into two parts (1) to demonstrate that the phenomenon was consistent with Emma’s identity formation and (2) to examine how Dale and Christy’s unique identities transferred into teaching identical lessons and content.

Emma’s scrupulous attention to safety in the lab, her concentration on work ethic, and her knack for classroom management were each evidenced in the field notes and one-on-one interviews [I, 29, 34, 37, 191, 247]. During her lessons and other daily activities, Emma displayed a straightforward attitude that was supplemented by a strong work ethic [I, 34, 70] and a disposition that commanded respect [FN, 78]. She credited much of this attitude to three key facets of her life and experience: being a mother [I, 29], working as a medical technician [I, 29], and student teaching [FN, 42]. She held the same high expectations for her students that she did for her children at home and for herself in the medical field. Her work in the doctor's office prior to becoming a teacher also provided her with a wealth of practical examples that she shared continuously [FN, 56, FN, 59]. For Emma, everything that occurred in the classroom was based on practical and logical reasoning to enable students to learn the content and be successful. Anything that distracted from tasks of necessity was considered a waste of time on an already jam-packed schedule [I, 38]. She recalled aspects of her former teachers and professors that served as inspirations for her own classroom. Her middle school science teachers [I, 32] and her high school biology teacher [I, 33] instilled in her a love for laboratory work that translated into her own teaching. At the college level, professors who made an impact on her were those who took time to tutor and did not turn her away when she was struggling [I, 34]. Emma strongly identified with one of her physics professors that shared a similar work ethic and became the person after whom she patterns much of her teaching [FN, 115]. She said,

Emma: He would explain anything, but the first thing he was going to ask you was how far had you gotten when you worked it out. And, if you said you hadn't tried, he said, well, you talk to me again when you have; because you do not get lost turning out of the driveway of your house. You get lost somewhere down the road.

[I, 34-35]

Each of these ideals and behaviors helped to define Emma's identity as a science teacher. She was working constantly, taking no down time during planning or after school. She was always grading papers, yet she was always willing to devote time to students before or after school to provide the help that they needed.

Dale and Christy were both teaching biology for the duration of data collection. The researcher noted how, although their lesson plans, handouts, and activities were identical [FN, 41], the classes did not seem to provide the same experience. After close examination of the field notes and comments made during the interviews, the emerging concept was that each maintained a different identity as a science teacher. Teaching styles were very similar with little deviation from the lesson plan. However, the mood set for the class and the engagement with students were determined more by teacher's identity. The kind of teacher that Dale conveyed was motivational, supportive, and humorous, while Christy exuded a more seamless and clinical persona that was equally effective. The researcher noted that Dale emphasized the common sense aspects of the science content, using situational examples and day-to-day scenarios to enable students to understand difficult concepts [FN, 13, 21, & FN, 47]. Analysis of field notes indicated that Dale strongly encouraged students to participate in open discussions throughout each lesson and seemed to quickly build connections with the students. He was constantly questioning students on the content, using a lot of prompts and praise for both correct answers and effort [FN, 45]. To break the monotony during lecture, he would add a humorous comment to refocus attention of the students or to help the concept stand out [FN, 264]. Christy's approach involved a strictly science approach that was very structured and organized. Explanations were always concise and to-the-point [FN, 69]. Occasionally, she would use a situational example, but primarily, she maintained focus on the scientific world when expanding on the content [I, 48]. While she did utilize questioning techniques during her lessons, she did not push for the same level of discussion that Dale sought. There was even a difference in the décor of their classrooms. This comparison goes beyond the fact that Christy was in the laboratory classroom with easier access to models and equipment, while Dale was in a typical classroom with only desks. The posters that decorated the walls were consistent with the identity each portrayed. All of the posters in Christy's classroom emphasized content, with a few focusing on encouragement or character traits. Dale's, on the other hand, were primarily motivational in context with the occasional science content poster [FN, 89-90]. One of his posters seemed to tie these two ideas together. "Most great inventions were once called impossibilities" [FN, 89].

Constant comparisons made between one-on-one interviews and informal conversations with Dale and Christy strongly supported the connection between meanings identified significant for engaging students and formation of identity within various communities of practice. Dale's inspiration to become a teacher was rooted in his enjoyment of working with kids through coaching [I, 57]. When asked about his path to becoming a science teacher, he said very little about his experiences in science class, stating that he could not recall a single professor's name. He described these experiences as more negative than positive, but he chose to teach science because of his high school biology teacher. She was described as showing a genuine concern for her students. He said, "She cared how we did, and she pushed us to do our best" [I, 52]. He acknowledged that his high school English teacher also had an influence on him as a teacher. He said, "It wasn't like it was a job to them" [I, 53]. While science content was still considered a high priority, it was not what Dale focused on when speaking about his own teaching.

Dale: I just try to take an interest in the kids, and if they're not doing as well as I think they should, I try to let them know that I expect more out of them, that they could do more. Just try to get to know them. You always find out stuff that goes on at home that, just some awful stuff, but it helps you kind of get to know them and what they might need a little bit more of… I just think just trying to teach kids that they can be more than they think they can be. Just try to help them…grow up to be responsible citizens.

[I, 55]

The behaviors that mattered most to Dale centered on the fact that these teachers took interest in and seemed to care about their students, and he applied these values to his own identity as a science teacher.

When Christy discussed her pathway to becoming a science teacher, she explained that her first career choice was pre-med, but that she hated dissections. She didn't remember liking science in high school, but when she entered college, she found the pursuit of scientific knowledge intriguing [I, 91]. What she enjoyed most was discovering the content on her own, deciphering through the notes and textbook to better understand the concepts, and not having everything handed to her [I, 91]. She said that she enjoyed every content area but physics. Her father did not want her to be a teacher, so she pursued a biology degree. After helping to tutor her brother, however, she decided that teaching was the path she wanted to take. When asked if she felt prepared to teach having gone into the field with no background in education, she insisted that the content was most important, but that classes on classroom management would have been helpful as she struggled through her first year of teaching.

Christy: I had the knowledge to begin with. I think that was…I mean getting a degree in the course that you are going to teach, I mean, that is the way to go. That's where you are going to get the most. I mean, honestly, with teaching, I think there are certainly ways you can tweak it, but I think it's either, you can do it or you can't. I think it is kind of a gift that people have.

[I, 20]

Christy began teaching at the age of 22, so she felt the need to set herself apart from her students who were only a few years younger. She explained that this has changed as she has gotten older, but she also said, "I do not want to be friendly. I do not want to be their friend. I mean, I will be friendly, and I will talk with them. But beyond that, I don't know" [I, 20]. Her identity as a science teacher was, in part, shaped by her own appetite for self-regulated learning in science and the survival strategies developed as a young teacher. These translated into the more content-focused and clinical aspect of her class.

From data analysis, the findings consistently demonstrated that each teacher maintained a unique teacher identity comprised of behaviors and convictions originating from various communities of practice, both past and present. Experiences as a student of science, participation in careers other than education, and other activities, both personal and professional, outside of the classroom contribute to the formation of teacher identity. Data analysis revealed a connection between the meanings and behaviors that teachers valued and the negotiation of those meanings in the science classroom. As teachers identify with behaviors that are meaningful and necessary for teaching science to high school students, these behaviors are negotiated as part of their own teaching identity. While this analysis touches on just a few aspects of identity, it was evident that the formation of each science teacher's identity was connected to the path that he/she had taken to become a teacher.

Mandated Policies

Through analysis of data, issues associated with mandated policies consistently emerged throughout the data. Although these demands and constraints were treated as part of the daily routine, the frustration associated with these mandates led to stress and self-sacrifice on the part of the science teacher. The theme was labeled as mandated policies to incorporate multiple categories derived from issues over which the teachers had little or no control. All policies associated with this theme allowed the teachers to have limited or no control over its use or implementation. These categories included curriculum standards, standardized testing, state regulations and monitoring, and local administration. Issues associated with these categories have been shown to cause burnout and stress-related illness in teachers (Borman & Dowling, 2008; Brown, Ralph, & Brember, 2002; Halim, Samsudin, Meerah, & Osman, 2006; Harris, Halpin & Halpin, 1985; Jepson & Forrest, 2006). At the time of this study, both the state and district level focus was on the implementation of the Common Core State Standards (CCSS). For science, this meant a push to improve science literacy (Anderson, Harrison, Lewis & Regional Educational Laboratory Southeast, 2012). Content for science was determined by the Georgia Performance Standards and evaluated by state standardized tests. Standardized testing was a major focus, as students were required to pass the Georgia High School Graduation Test (GHSGT) in science in order to graduate. End-of-Course-Tests (EOCTs) were required for physical science and biology. Adding to the stress, the school was under a state mandated Corrective Action Plan [FN, 283] due to not meeting annual yearly progress (AYP) for the past five years.

Results for this theme were divided into three domains of focus to help define the culture of science education in this school: (1) *teaching the standards and preparing for standardized tests*, (2) *addressing the added requirements*, and (3) *responses and repercussions.* By focusing on these three domains, the researcher was able to present teachers' behaviors and concerns concerning mandated policies and highlight the impact it had on them both professionally and physically.

Teaching the standards and preparing for standardized tests. All science content courses were governed by the GPS. When asked about their approach to teaching science, every participant commented that the standards were top priority [I, 11, 22, 45, 58] when determining what to teach. However, there was some autonomy in how it was taught [I, 22]. All teachers were required to post the standards on the board as they were taught [FN, 10, 35, 143] along with the essential questions that accompanied the content. The science teachers updated these during their morning planning period as needed [FN, 103]. At the beginning of each lesson, a warm-up activity was given that was comprised of two review questions [I, 11, 21, 45, 276]. Questions were selected to address standardized test content and did not always match the topic of the lesson. Curriculum maps [I, 38] and lesson plans [FN, 103] were submitted to the school administrators to provide evidence that all standards were covered, and the administrative team would walk through on occasion to ensure the lessons matched the lesson plans.

Curriculum maps [I, 38] were designed to ensure that enough time was allotted to each standard and that all content was covered prior to the test date. Time was a limiting factor that prevented the teachers from elaborating beyond the required content. The following excerpt from Emma's one-on-one interview demonstrates an example where she felt certain content was necessary to prepare students for biology, the next course in sequence, but because the GPS requirements were locked in, she could not deviate from the standards.

Emma: The tests that they take at the end of the course and the graduation test drive everything we do. That's sad isn't it? Just like, I'll give a for instance, I think that the organic chemistry that I taught in physical science [prior to GPS] is necessary. It is not a standard anymore. I cannot afford the time because I have to teach the standards that they are going to be tested on. I don't even have a day to take to talk about the fact that we need to know about nucleic acids and carbohydrates and lipids, and I mean; we don't even have a day to talk about that! And, I used to do a whole little unit on that. I mean, we even built structures with marshmallows of alkanes, alkenes, and alkynes so that they would understand the bonding, the single, double, and triple bonding that goes on. We don't have time to do that. They took it out of the chemistry standards. Ruth doesn't teach it either. So, nobody teaches any organic in high school. None! It's the basis of life, and we don't even teach it because the state says we don't need to. And, I just think they understood a little bit more about that part of biology when they had a little bit of background to go with it.

[I, 44-45]

She explained that the standards for biology required that students understand the function of carbohydrates, lipids, proteins, and nucleic acids, and that it would make sense for there to be standards for physical science to help them understand the structure of the molecules. To her dissatisfaction, there was no time to add this content to the schedule. Dale expressed a similar frustration about not having enough time to address topics that arose during a lesson that sparked student interest.

Dale: Everything is just so compact… You got to get it done, but also, you know, I tell them all the time to ask questions, that's how you learn. There will be times that they'll ask good questions. You can tell that they're thinking. It might not be something that's going to be on the graduation test of the end of course test, but to me, I'll still go into it and go a little over the top. You know stuff they're not going to be tested on, but it is stuff that they are interested in to maybe spark some of that interest. But, the vast majority of is all about the test.

[I, 57-58]

Although these questions were not focused on the standard and despite the time constraint, Dale embraced the teachable moments to engage students in learning. At the same time, Dale expressed that there was very little autonomy in courses like biology that had an EOCT [I, 58]. Therefore, the ability to elaborate on the teachable moments was limited by time needed to teach the standards. Ruth remarked that with standardized tests looming overhead, the pressure to cover standards translated into a less than pleasant experience for students.

Ruth: The kids are just tested to death. They are always saying that they are tested to death. They tend to, in my opinion, flourish and have more time to integrate the knowledge when they're not preparing for some standardized test all the time, but that's the world we're stuck with.

[I, 13]

And the responsibility fell to the teacher to ensure that students were prepared for the test. Through daily preparations and planning ahead, they were able to address the standards. Pacing guides [I, 23] developed in conjunction with curriculum maps helped to keep teachers on target to cover all standards.

Addressing the added requirements. In addition to teaching the content established in the GPS, there were other mandates that followed, from both the state and local level. The CCSS were in the early phase of implementation, and the school was pushing for the incorporation of reading and writing in the science classes. In addition, the administration required that all teachers demonstrate the use of certain pedagogical strategies within their lessons. Analysis of data showed that teachers were often reluctant to fully implement strategies or policies that they felt hindered their ability to teach effectively. The degree to which they incorporated the new requirements depended on how well it fit with what they were already doing in the classroom. Having to address these requirements on top of an already demanding schedule resulted in teachers searching for creative ways to squeeze the latest strategy into their lesson plans or being forced to defend their reasons for not incorporating certain strategies.

In response to the CCSS and its emphasis on science literacy, the school administration required that science teachers include a segment in their lesson plans that demonstrated how these standards were addressed. In addition, they were to highlight the portion of the lesson that reflected use of literacy so that it would be easy to distinguish when lesson plans were checked [FN, 113]. Incorporating literacy into the lesson plan was no problem since literacy was already a large part of their curriculum. However, the science teachers did not see eye-to-eye with the administration on how literacy should be implemented in science. The argument was that they were already incorporating reading and writing, and there was no need to change a system that was working. Each science teacher required his/her students to write laboratory reports, read current events in science, write article reviews, and read the science textbook. However, this was not enough to satisfy the school’s requirement. Emma explained that the school was pushing for everyone to include persuasive writing in their classes, a form of writing that was rarely used in scientific writing [I, 46]. Instead of conforming to the rules, she defended the stance held by the science department and insisted they continue what they were already doing. The form of writing primarily used in science, she explained, was predominantly expository writing. They had no time to add persuasive writing, and while it may be appropriate for some topics in biology, she said to incorporate it in physical science or chemistry would be difficult. She said, “I told them, you’re just going to have to be satisfied with what we already do” [I, 46].

Data analysis revealed that pedagogical strategies required by the school administration and the state were a source of frustration and anxiety for the science teachers. There were two strategies that were referenced multiple times in the interviews and field notes. The first was simply a structure to the lesson plan that would provide an “opening, middle, and closing” [FG, 81] to the lesson. None of the teachers denied that this was a sound structure for a lesson plan format. The issue revolved around timing and the extra time required for incorporating the “opening” and “closing.” The argument was that being a bell-to-bell instructor means you are teaching right up to the bell and don’t always have time to stop ten minutes early for a closure [FN, 247, 264; I, 46]. The result was that, those who were good at incorporating the “opening, middle and closing” used it. Those who were not good at it put it into their lesson plan, but continued to conduct their lessons bell-to-bell without stopping early to formulate a closure. Closures were used only when matching the normal flow of the lesson. The following dialogue from the focus group interview demonstrates how the teachers felt about the new requirement:

Christy: Well, we’ve got to follow the opening, middle, and closing.

Emma: Gah, yeah!

Ruth: Opening, middle, and closing. Yeah, that stuff.

Christy: Basically, I’ve just got to fit it into what I naturally do and make it look like I’m doing that.

Emma: Yeah, me too. On my lesson plans, it will say before, during and after. Now, whether that really fits in with before, during and after, I don’t know. I just divide stuff up.

Christy: That’s right.

Emma: And to make it look like that so that it says it on there, but I'm going to do what I want to do. And honest to goodness, nobody knows whether I'm doing it right or not. I mean really.

Christy: We're not getting any feedback anyway. I mean, even when we have people walk through. I've had two in the last two weeks, and I've had no feedback, so I don't know.

Emma: [laughs] Yeah, if we're doing it wrong, we don't know.

[FG, 82]

Similar reactions and frustrations encircled a second required strategy, differentiated small group instruction. This strategy was presented to the school through staff development and was being incorporated in hopes of addressing the needs of diverse students in the classroom. This form of instruction was not simply differentiation of instruction, but was instead, a form of tiered instruction [FN, 321] in which students were placed into homogeneous groups based on ability level. It was designed to be a cooperative group activity that allowed advanced learners to receive enrichment assignments while other groups were given assignments based on the specific need of the group. Teachers were instructed to be facilitators and move from group to group to provide individualized instruction. Through all participant observations, not a single example was noted of this strategy being used. Ruth explained how she used this strategy once to teach balancing equations, and refused to use it again.

Ruth: We were told we had to differentiate and put them in small groups; that we could not put one high functioning learner in with some intermediate learners and people who were struggling. They had to be all in one level. You had to put all the high learners together, all the intermediate learners together, and all the struggling learners together. Which, you wonder, okay, how are the struggling learners ever going to figure out what's going on. My experience was, I spent most of my time with the struggling learners, had very little time to get around to the other people. So, they were frustrated, and the grades on the quiz and the test that I gave after that were just very very unsatisfactory compared to the grades that I usually got on balancing equations. Therefore, I returned to the previous way that I taught balancing equations, and I have never gone back to that differentiated small group

> setting again. It was a disaster, so when an administrator comes in and says, we need to see more differentiated, small group instruction, I think “Okay, so… you’re going to force me to do something that I have seen did not work for my students just because we need to see small group differentiation?” So, that’s my problem. That if I do something and it doesn’t work, why should I continue to do it just because somebody says this is what the state wants us to do now…Do you put the good of the child’s education over compliance with the state’s mandates?

[I, 95-96]

Ruth defended the use of strategies proven to work in her classroom. Data analysis provided evidence that, although this was a required strategy, the science teachers refused to use it.

Data analysis consistently demonstrated that mandated policies were used only when they did not disrupt the natural flow of instruction. The participants described themselves as rule followers [FG, 87]. Their lesson plans included all required elements and were turned in on time. They performed all the day-to-day functions required of teachers in the school to the point that the principal often used the science department as an example for others to follow [FG, 88]. However, the rules that they were willing to follow were those that did not interfere with teaching students in a manner that they thought was right. Conforming to the rules occurred on their own terms, often sneaking and doing what they felt was best for the students [I, 79]. As long as their students maintained high test scores, they did not receive much argument from the administration. In fact, they recalled the principal saying, “What they do works, don’t mess with it” [FG, 83]. Emma followed this comment by stating that this only added more pressure to the demand of keeping test scores high.

Responses and repercussions. After five years of not making AYP, the school was subjected to a Corrective Action Plan [FN, 283]. Part of this plan involved having outside observers enter the classrooms to evaluate performance and check to see that teachers were following procedures established in the plan. While science scores for the school were good [D, 16; I-82] and had no impact on the NI-5 status, the department was still observed on a regular basis. Ruth stated, “The powers that be need to trust teachers” [I, 3]. Christy described the observations as being a huge distraction, interfering with the students’ ability to interact with the teacher [I, 22]. She related a story about an English teacher who had received 40 observations within a two month period. Not long after that, she retired and went to the middle school as a gifted teacher to avoid the stress. Christy said, “When I can afford to, I will get out of here and enjoy the rest of my life” [I, 23]. With all of the observations, the science teachers claim that they received no feedback and no support. While all other departments had a content expert to provide feedback and support, there was no one for science [FG, 82]. This was seen in two lights. In the negative light, it was seen as a lack of support. In the positive light, they were given slightly more autonomy because there was no one to force changes on them. They credited this to their test scores, stating that, as long as everyone was satisfied, they could continue doing what they wanted to do. However, continuously having others in the room observing made both the students and teachers nervous [I, 13].

Analysis of data showed that mandated policies led to intense pressure on the science teachers to keep test scores from dropping. Frustrations ensued from these pressures that resulted in an overpowering sense of commitment to ensure that all standards were covered for the tests. Although they seemed capable of managing the workload and negotiating for themselves what works for their students, the pressure forced them to sacrifice of their own wellbeing to ensure that students receive the best science education possible.

In response to the demand for maintaining high test scores, the teachers literally “work themselves sick” and “work while” they’re sick [FG, 89]. They feared being absent from school because the time lost would impede students’ ability to perform well on the test. Christy shared frustrations over missing school for maternity leave [I, 70]. Despite thorough planning and ensuring that each day was fully prepared with copies and instructional material, her long-term substitute refused to follow the prescribed lessons. Therefore, she was required to redeliver all of the standards missed while that teacher was in charge. Emma expressed concern over missing school for her son's college graduation [I, 38] because she did not want to be absent so close to the EOCT dates. She had entertained the idea of not going, but decided that she would make it work. Ruth had just undergone a series of illnesses and family crises that she feared would take her out of the classroom. Among these were breast cancer, diabetes, high blood pressure, and shingles. While the shingles episode occurred during the summer, she was still on medication to prevent a recurrence. In the previous semester, her mother-in-law, for whom she and her husband were caretakers, passed away. "One day at a time," she said "we will get through it" [FN, 159]. She expressed that everyone had been very supportive during her battle with breast cancer. Her husband became a substitute teacher to take on her classes while she endured chemotherapy, but she made arrangements to leave school early for chemo treatments, never missing a single day. The principal told her that, had they not known the situation, they have never guessed anything was wrong. Instead of taking time off to heal, she turned the experience into a teaching tool, taking the opportunity to teach her students about the effects of radiation.

All participants in the study worked late hours, and rarely took time to relax during the school day. Even lunch was a time to work out the details of classroom management, curriculum issues, and other concerns. When extended time after school was not enough, they took work home with them [I, 47]. The following discussion was from Ruth's one-on-one interview:

Ruth: It's not a 9 to 5 job. It's a 24 hour a day job. You carry home your grading. You carry home your concerns about students. You still have to try to function as a spouse, and in some cases, a parent, and then, in cases, as a caregiver of older

> family members. There are all these outside concerns that you need to take care of as well. So, it really helps to have a supportive family.

[I, 17]

Ensuring that students receive feedback for their work and taking time to setup laboratory experiments were all part of teaching the standards and preparing students for standardized tests. Although, there were no policies requiring teachers to working late hours, time taken away during planning periods for PLC meetings, covering other teachers' classes, and other issues forced them to shift the work to a later time.

Analysis of the theme evidenced that teacher frustrations associated with mandated policies was high. The demand on teachers to address all standards and ensure that students pass standardized tests was exacerbated by the added pressure of a Corrective Active Plan. The science teachers in this community of practice (Lave & Wenger, 1991) worked hard to ensure that all standards were covered prior to the tests and evidenced this through their lesson plans and curriculum maps. As more requirements and restrictions were established by the school or the state, the teachers in the science department used their own judgment to determine if something was appropriate for their students, sometimes overtly refusing to incorporate certain strategies such as tiered differentiated small group instruction and the use of persuasive writing over expository writing. The price of ensuring high test scores in science was great, forcing teachers to make sacrifices that meant putting the needs of the students ahead of their own.

Findings from the data analysis suggest that the culture of science education within the context of this small rural school was defined by three key themes: *constant collaboration, teacher identity,* and *mandated policies*. Each theme was evidence through the sociocultural interactions between science teachers and others that engaged in their community of practice (Lave & Wenger, 1991). The theme of constant collaboration demonstrated how teachers within the community depended upon one another, knowing that each of the other members was hard working, dependable, and knowledgeable in his or her own area of expertise. The theme of teacher identity was rooted in the teachers' own identity formation that involved the negotiation of meanings contributing to the kind of teacher that they appeared to be in the science classroom. Through a social constructivist (Vygotsky, 1978; Wertsch, 1998) lens, the data analysis revealed that the teachers' identities were strongly connected to their experiences both as a teacher and in other activities leading up to becoming a teacher. Valued traits and behaviors that each encountered were assimilated into his or her unique teacher identity; while traits that were considered negative were purposely avoided. Data analysis found that under the theme of mandated policies, science teachers experienced frustrations and concerns associated with the demand to meet state standards and ensure that students were prepare for standardized tests. While analysis of data showed that teachers found ways to circumvent policies that hindered instruction, the looming threat of change if test scores dropped forced them to sacrifice time and health to ensure that standards were taught correctly and according to plan.

Result: Informing Teacher Practice

The data analysis consistently found that, for research question two, teacher practice was informed by the culture of science education within the following themes: *instructional method* and *laboratory work*. Evidence to support these themes was derived from comparisons of field notes and interview transcripts. The theme of *instructional method* focused on how aspects of the culture of science education informed the type of strategies used in the classroom. Various strategies observed and discussed included direct instruction, guided practice, cooperative grouping, questioning techniques, and laboratory work. The theme of *laboratory work* went a step beyond the methods of science used in the classroom to seek information on the frequency of laboratory use and the degree to which inquiry was applied.

Instructional Method

The choice of instructional method used in the classroom was based on different aspects of the culture of science education. Evidence to support this theme was derived from field notes taken while observing lessons and interview transcripts where teachers were asked to discuss how various aspects of the culture influenced their practice. Through analysis of data, three categories were found to support the theme of instructional method: *using what works, sharing ideas*, and *perceived autonomy.* Constant comparisons (Strauss & Corbin, 1997) were made between the observations in the classrooms and personal reflections of the teachers regarding their personal path to becoming a science teacher and what had the most influence on their approach to teaching. It was found that collaboration, teacher identity, and mandated policies each contributed to choices made regarding pedagogy, types of laboratory activities, and other practices used in the science classroom.

Using what works. Data analysis consistently showed that all four science teachers depended heavily on direct instruction and laboratory work to teach the science concepts [FN, 11, 61, 178, 294]. Interviews transcripts supported this as each one confirmed that they felt direct instruction was the most effect method of ensuring that students learn science content [I, 4, 21, 43, 56]. It was noted that, while the teachers felt strongly about the need to use direction instruction, their comments regarding its use seemed almost apologetic and other times seemed defensive. The following two excerpts were from the one-on-one interviews, but the defensive tone was consistent through informal discussions as well:

Christy: I still do a lot more direct instruction than we are probably suppose to do, but I just don't…kids can't discovery what I'm teaching on their own completely.

[I, 21]

Emma: Well, I'll tell you this, a lot of people frown on direct instruction. I honestly don't know why. Because if they knew everything before they got to me, there would be no need for me. I believe in direct instruction.

[I, 43]

The question that prompted these answers was, "What do you consider to be your primary pedagogical strategy?" The researcher did not suggest or imply that direct instruction was unacceptable. However, the general consensus among the teachers was that this was not the type of instruction that the state and local school administration wanted to see. However, they felt it was the most efficient means of covering the standards and ensuring that students received accurate information [I, 4, 21, 43, 56]. The following excerpt was taken from a focus group interview. It sheds light on how strongly the teachers felt about direct instruction:

Ruth: With the amount of content we need to deliver, we still do a lot of direct instruction.

Christy: We're one of the only ones who still do a lot of direct instruction.

Emma: I know, and if our scores weren't so good, they'd be on us about it. But it's kind of hard for them to argue about it. Now, if it comes to a point where our scores aren't as good, then they would probably take a harder look. But now, they don't have anybody that can tell us anything. I mean, who's come from the state that can tell us anything? Nobody!

Christy: The kids on a regular basis though, even though they might complain about notes, they appreciate the fact that we stand up there, and we tell them and talk to them.

Emma: Right. And have those kinds of conversations to explain content. You know what I'm saying? Because, I think they're more or less expected to dig it out on their own. And, while there is value in that, you do not have time. You will not get as much done, and the state is going to ask them questions about any of the standards that you're suppose to have taught. So, you know, do I not teach it to them and make them dig it out on their own more? Or, do I do a half-and-half kind of thing, which is what we try to do. There's going to be some times when you're going to have to dig things out on your own, but then, there's going to be other times when I'm going to explain it to you. I'm going to make you practice it, and we are going to move on.

Christy: Well, my thing is if they could dig it out on their own, why would I even need to be in there?

Ruth: Right. It's a technical subject, so there's only a certain amount that they could explain to themselves.

[I, 69-70]

The issues brought to light in this dialogue referenced discontent associated with the impact of mandated policies on teacher practice. The demand to cover all of the standards and prepare students for standardized tests served as a major constraint in the choice of pedagogical strategy. As noted previously in the theme of mandated policies, not having enough time to cover all of the standards was identified as a source of frustration for science teachers. As Emma suggested, there was no support from the state, no guidance, to provide them with a more efficient and effective model than direct instruction [I, 40].

While direct instruction was the dominant form of instruction, it was not the only pedagogical strategy used. Strategies such as guided practice and questioning were used to supplement and enhance lectures. While, cooperative group activities were reserved for what they called "dry chapters," content chapters that did not have a suitable laboratory activity [I, 11, 50]. For example, Emma preferred for her lectures to be "as interactive as possible, have a lot of conversation" [I, 43]. For topics like models of atomic structure, this was difficult. With no suitable laboratory activity, she did not want to "stand up there and talk about those men and bore them to tears" [I, 50]. So, she developed a jigsaw cooperative group activity to work through a large amount of information in a more interactive way. Questioning techniques were also observed, particularly in Dale's classroom, which held students responsible for listening during class [I, 56]. The strategy that he used made the classes more positive and interactive, a quality that matched well with his teacher identity. Ruth used a lot of guided practice in chemistry [FN, 144-146] that enabled her to work with students one-on-one. Organizational techniques were also used for both direct instruction and independent practice. Guided notes and notebooks were used in all four classes, and graphic organizers were also common, particularly in the form of concept maps. At least one example of a foldable was noted for biology [I, 24]. Christy also spoke of a Three Stooges comic story that she used to teach respiration for her human anatomy and physiology class [I, 21]. So, while the predominantly used strategy was direct instruction, the teachers did make variations to instruction whenever they considered it more appropriate.

Sharing ideas. Data analysis found that the primary source of gathering new ideas and pedagogical strategies was from collaboration and sharing with other teachers. While certain staff development opportunities were helpful, the teachers would have to pick and choose [I, 6] which strategies fit best with their content and teaching style. The constant collaboration that occurred within the department allowed for sharing of ideas about content and ways to improve teaching skills. In her one-on-one interview, Ruth expressed how valuable this type of collaboration was to her as a beginning teacher, and how she continues to value ideas shared with colleagues.

Ruth: My colleagues. I've learned a tremendous amount from the ones who have been here longer than I have. My mentor teacher was instrumental to my survival the first two or three years that I was teaching, and has remained a really good mentor. So, watching how she did things, and having conversations with her helped a great deal. My colleagues in the science department, by watching them and listening to them talk, I've picked up some of their practices.

[I, 7]

Christy also felt that sharing with other teachers had the greatest impact on her choice of strategies. She said, “Just the exposure to other teachers and just being willing to take what others will give you and to share what they’ve given me to other people” had influenced her teaching the most [I, 20]. She reflected about how her former school district gathered all of the science teachers together during the GPS roll out so that they could share all of their activities and ideas. They developed a notebook of materials that she was still using in her classroom [I, 25]. She said, “I still talk to some of the people that I taught with…so, we go back and forth with anything new that they have, like the Three Stooges [activity]” [I, 25]. Emma reminisced about collaborations that occurred through PRISM. The collaboration with university faculty and science teachers from other school districts provided insights into what students could expect at the university level. She explained:

Emma: I felt like those kinds of relationships, partnerships that were formed where invaluable to me. I learned a lot about what goes on post-secondary, and that’s always a help those of us who are trying to get [students] prepared for that. And the technology because the world is changing and we need to change with it. And, even though they come from a rural high school, I don’t want them to get to college and think they… that they experienced so many things that they’ve never seen before. Because then they will be thinking back and saying, God, why didn’t they tell us this. Why didn’t they have us use this? Why don’t we know this? And, I want them to get there and have a lot of those kinds of… I just want them to be as prepared as possible, and have as many experiences as possible.

[I, 37]

The ability to share ideas and strategies with colleagues, both at the high school and university levels, was considered the most valuable source of pedagogical strategies. If the strategy was proven to work by someone that they considered trustworthy, like a colleague, then they were more likely to use, or at least try it in their own classroom.

Perceived autonomy. Each teacher was asked to share his or her thoughts on autonomy. Answers varied, and there seemed to be inconsistencies between answers to this question and to ones regarding their choice of pedagogy. Analysis of data established that while teachers perceived a great deal of autonomy in choosing their strategies, reference was consistently made to constraints such as time and standardized tests as reasons to choose direct instruction over another pedagogical strategy. There was no choice of what topics should be covered. This was established in the GPS, and the teachers felt they should not deviate from the established standards [I, 11, I, 22, I, 58]. However, there was a perception that they had "quite a bit" [I, 11] of autonomy regarding how they were taught. The following excerpt was consistent with responses of other participants.

Christy: The topics are locked in, but I have a lot of autonomy on how I teach it. And, I think that will continue as long as our graduation tests stay up. But I do worry that biology EOCT has a lot lower pass rate than the other EOCT (physical science and graduation test). I worry when it becomes one of the main focuses for AYP that if those stores don't come up, then there will be some interference. But then I would have a huge problem.

[I, 22]

Thorough analysis of teacher reflections continuously demonstrated that to use a primary method of teaching other than direct instruction for most content would lessen the ability to cover all standards in time for the standardized tests. As Christy reiterated in the above comment, as long as the test scores remained at an acceptable level, the strategy being used would not be challenged by the administration. Dale was the exception to the group, explaining that with biology, there was very little autonomy [I, 58]. He and Christy used the same lesson plans to teach biology, and in the previous semester, he and Emma did the same. It was during his one-on-one interview that he revealed who made most of the choices about how it was taught.

Dale: Well, in physical science, we do exactly what Emma wants because she's done it a long time, and that's just… You know, I'm getting more… I taught it… this first semester might have been only the second time that I taught it. I think the first year I was here, I taught it, and maybe one other time. And then, with

> biology, I mean, most of it's what Christy wants to do, but a lot of stuff that she does is very similar to stuff that I've already done before.

[I, 59]

He continued by saying that he was able to use some of his own activities, but mostly, he used the lessons and activities that the other teachers wanted. He explained that doing so gave him confidence that he was doing what needed to be done for the students [I, 60]. There were receiving the same content and very similar experiences in the laboratory.

Laboratory Work

In addition to direct instruction, laboratory work was considered one of the most important aspects of learning science. Data analysis found that getting students into the lab was a top priority, but there were limiting factors that determined how often and how in depth these lab experiences could be. The two categories that support the theme of laboratory work included: *frequency of laboratory work* and *depth of inquiry*. Hofstein and Lunetta (2003) argued that many teachers are reluctant to incorporate laboratory activities based on a belief about what must be done to achieve desired learning outcomes. Data analysis supported this statement, but also that there are additional factors that limit both the frequency and the depth of inquiry at which laboratory work was used.

Frequency of laboratory work. There was no question that laboratory activities were an essential component to teaching science in all content areas. When asked about primary teaching strategies, the teachers would respond with direct instruction and a lot of labs [I, 11, 21, 43, 56]. During the first week of observations, there were no laboratory activities in any of the classes. This time was reserved to teach about laboratory safety. The teachers refused to begin laboratory work without ensuring that students were familiar with the layout of the laboratory, the location of safety equipment, and the proper safety attire to be used when in the lab [FN, 5, 28]. After that, use of the laboratory was determined by the content being taught.

Ruth: As far as when we do lab, it's sort of a matter of when we get to the place where the lab would bolster the content. For example, we're about to go into a chapter on matter, and we have three labs, or I have three labs that go with that chapter: Law of Conservation of Mass, Law of Definite Proportions, and Density of Solids and Liquids. So, in one chapter there will be three labs. Whereas in the atoms chapter, it is difficult to do a lab on that content exactly. You can do like drawings, and they'll have diagrams to do so they'll have hands on things… But as far as the labs, it depends, as I say, there might not be a lab in one chapter. There may be three in the next chapter, but I try to average probably one every couple of weeks. And, then some small activities and demonstrations, too.

[I, 11]

Although they were unable to get into the lab every week, Ruth made sure there was some type of activity to supplement the direct instruction. Christy described a similar scenario. Where topics like cells could allow for laboratory work at least twice a week, she did mostly group work with ecology because she did not have "a lot of lab stuff" for that topic [I, 22]. Getting into the lab required a little more work for Dale since he did not have a laboratory classroom, but he and Christy made arrangements whenever necessary so that he could use the same laboratory activities that she did.

Emma: I believe in getting in lab. I try to do one lab with every chapter I teach. Hopefully making sure that they are in lab at least once a week, so that they can have the opportunity to put what they know to use and make some connections between the two.

[I, 43]

Data analysis consistently demonstrated that participants considered laboratory work to be an essential component of their practice. However, getting into the laboratory could not be whimsical if these experiences were going to optimize student learning of the standards. It must be planned and properly incorporated into the flow of the lesson. As Ruth stated, laboratory activities were used when they were thought to "bolster" the content [I, 11].

Depth of inquiry. Data analysis showed that while there was a large amount of laboratory work, very little of it was inquiry-based. There were no instances of open-inquiry or full discovery type laboratory activities. When asked, the teachers responded that they did some guided inquiry, but time did not permit anything more [I, 30]. During an interview, Emma pointed out:

Emma: Those kind of labs take a long time. They take about twice as long as anything else you do. And [my science method professor], he said you're not going to be able to do this with every lab, and you should not with every lab. But if you only do one a semester or two a semester, then that will be better than none. It will prepare students more for what science is really like if you can manage to do that. He said, I know your time is short. That's a very realistic attitude, and I can live with that. So, that's kind of what I've tried to do.

[I, 30]

During this time, Emma was to videotape herself while conducting a guided inquiry laboratory. The assistant superintendent wanted to use her example as a guide for other teachers in the district to follow [I, 31]. Emma argued that the students were not prepared, especially the ninth graders that she taught, to be turned loose in the lab with no directions or guidance. In the field notes, it was indicated that she planned to conduct two guided inquiry labs throughout each semester, but that there were a lot of "cookbook" labs because they were quick and easy to do [FN, 57]. This would allow her to get the students into the lab more often. Ruth commented in the focus group interview that, "The state has an unrealistic perception of just how many inquiry labs and tasks and projects you can do with the amount of content we deliver" [FG-69]. Dale added that they did some inquiry activities in biology, but that students were "not very good at that" [I, 56]. Even with the element of inquiry, the guided inquiry classroom did not replicate the culture of science with its complex mixture of beliefs and traditions (Latour & Woolgar, 1986). Instead, students in a guided inquiry lesson collaborate to develop a single experimental design, all utilizing the same equipment and scientific practices that will lead to a foregone conclusion. Otherwise, the inquiry lesson would take away from valuable time needed to cover the required standards.

Data analysis consistently showed that the culture of science education informs teacher practice in two major areas: *instructional method* and *laboratory work*. Each of these themes emerged through constant comparison (Strauss & Corbin, 1997) of field notes and interviews with individual teachers and with a focus group. It was found that direct instruction and laboratory work were the two most common strategies used by the participants. Data analysis found that the culture of science education influenced teacher practice by adding limiting factors such as time constraints, pressure to teach all standards, and strain of ensuring that students were prepared to pass standardized tests. Though teachers felt they maintained a certain degree of autonomy, the looming demands established by standardized tests resulted in most of the lessons being taught as direct instruction due to the efficiency of this strategy. While some variation was incorporated, it was only used when the teachers felt the content was boring or there were no laboratory activities to accompany the chapter. Laboratory work was limited to only a few guided inquiry activities, but efforts were made to get students into the laboratory every week.

Summary

The purpose of this study was to define the culture of science education within the context of a small rural high school and to determine how this culture informed teacher practice. Data was analyzed using principles of grounded theory (Strauss & Corbin, 1990) that allowed for themes and patterns to emerge directly from the data. As initial categories began to come together through inductive coding procedures, the researcher used constant comparisons (Strauss & Corbin) to ensure that the phenomena held constant across data sources and across participants in the study. This study focused on the sociocultural interactions among science teachers in a community of practice (Lave & Wenger, 1991) to better understand science education within the context of the small rural high school. Through data analysis, the researcher determined that five themes emerged in response to the two research questions: (1) *constant collaboration,* (2) *teacher identity,* (3) *mandated policies*, (4) *instructional method,* and (5) *laboratory work.* The five themes provided a framework for the study to better understand the culture of science education. Results were discussed in two sections. Findings from the two research questions revealed that the culture of science education was strongly influenced by the collaborative nature of the science teachers, the formation and negotiation of teacher identity, and by policies established by local, state and federal mandates. Also, data analysis found that teacher practice was affected both in their choices of instructional method and in the depth of inquiry used in the laboratory.

CHAPTER FIVE: CONCLUSIONS

In an age of accountability, science teachers are challenged to provide students with authentic scientific experiences while still preparing them for standardized tests. The framework for what science teachers use in the classroom is established in the state and national science standards, and the tests are linked to these standards (Achieve, Inc., 2013; NRC, 1996; NRC, 2011). While there are many factors that influence the content, materials, and pedagogy used in the classroom, the choice is ultimately in the hands of the science teacher (Weiss, Pasley, Smith, Banlower, & Heck, 2003).

Science teachers are faced with demands to cover all science standards necessary for students to pass the end-of-course tests. In addition, science classes are expected to include robust learning activities and laboratory experiments to enhance learning of the standards. The time required to develop quality lessons that include authentic laboratory experiences and provide students with adequate feedback from assessments is extensive, causing high levels of teacher stress. High levels of stress result in frustration and anxiety in the field of science teaching (Harris, Halpin, & Halpin, 1985). Consequently, studies have shown that science teachers are more prone to intense pressure and stress than are non-science teachers (Halim, Samsudin, Meerah, & Osman, 2006). As pressures rise to ensure that schools meet required state standards, the ability to recruit and retain good science teachers is of great concern. As a result, understanding how science teachers deal with the strain of meeting such arduous demands becomes a top priority if school administrators are to provide them with the support and professional development that they need without intensifying stress levels.

To provide a perspective from the standpoint of the teacher, it was necessary to develop a better understanding of the culture in which science teachers practice. This study sought to define the culture of science education and investigated how this culture impacts teacher practice in the science classroom. For the purposes of this study, the researcher positioned the culture of science education under the umbrella of the culture of science, implying that the culture of science informs the content, along with certain values and expectations that teachers must disseminate to students in the science classroom. This study recognized that science teachers are members of a community of practice (Lave & Wenger, 1991), and thus, construct knowledge and meaning through participation in social interactions (Vygotsky, 1978; Wertsch, 1998) that occur within the community.

This chapter provides a brief overview of the findings from this study beginning with the themes that emerged from the principles of grounded theory development (Strauss & Corbin, 1997). The two research questions are revisited before discussing the findings. The two sections that follow include a detailed discussion of the findings relative to each of the two research questions. From this discussion, the researcher addresses the implications for teacher practice, for teacher education and professional development, and for research. The chapter is concluded with brief remarks and recommendations for further study.

Findings

The researcher found that the culture of science education within the bounded context of this case study (Stake, 1995) was defined, not only by the powers and policies imposed upon teachers, but also by the teachers' resilience and personal conviction to ensure student learning in the science classroom. The collaborative nature exhibited by the participating science teachers along with their unique teacher identities helped to form a supportive and knowledgeable foundation upon which the community of practice (Lave & Wenger, 1991) thrived and, in times of distress, survived the onslaught of demands for which they were held accountable. This study also found that the culture of science education impacts teacher practice in both the form of instructional method used in the classroom and in the depth of inquiry implemented during laboratory investigations.

From the systematic procedures of grounded theory development (Glaser & Strauss, 1967; Strauss & Corbin, 1997; Strauss & Corbin, 1990), the following five themes emerged: (1) *constant collaboration*, (2) *teacher identity*, (3) *mandated policies,* (4) *instructional method,* and (5) *laboratory work*. The five themes provide a framework for describing the culture of science education through the social interactions and day-to-day activities of the science teachers within the community of practice (Lave & Wenger, 1991). Each theme emerged in response to the research questions and was supported consistently by data analysis. The two research questions that guided this study were:

1. What defines the culture of science education?
2. How does the culture of science education inform teacher practice?

The following sections address findings in relation to each research question.

Discussion of Findings

To better understand the culture of science education and how this culture informs teacher practice, the researcher approached this study through both a social constructivist (Vygotsky, 1978; Wertsch, 1985) and ethnographic (Denzin & Lincoln, 2003; Geertz, 1973; Goodenough, 1970, 1981; Lincoln & Guba, 1985; Merriam, 1990; Stake, 1995) perspective. These perspectives provided a framework that allowed the researcher to view findings from multiple viewpoints (Eisner, 1991). Each participant maintained a unique perspective that worked synergistically with other members of the community of practice (Lave & Wenger, 1991) to ensure student learning and successful performance on high stakes tests. This study focused on the social interactions among the participants and with others within the context of the school. Also, participants were provided with opportunities to reflect on their own experiences and paths to becoming a science teacher through the use of one-on-one and focus group interviews. This section includes a discussion of these findings in conjunction with the two research questions that guided the study.

What Defines the Culture of Science Education?

In response to the first research question, three themes emerged to provide a framework for defining the culture of science education: (1) *constant collaboration,* (2) *teacher identity*, and (3) *mandated policies*. Each theme provided a way of looking into the culture and understanding the interactions and influences impacting teacher choice and the day-to-day experiences of the science educator.

Constant collaboration. Findings from data analysis consistently demonstrated the significance of constant collaboration within the community of practice (Lave & Wenger, 1991) was a contributing factor to the culture of science education. Two core domains emerged to support the theme of constant collaboration: (1) *forced collaboration*, and (2) *unforced collaboration*. Forced collaboration involved communication that was structured by the administration, allowing the teachers limited freedom over what was discussed and accomplished. Unforced collaboration, on the other hand, occurred without pretense and proved to be valuable and productive in meeting the immediate needs of the teachers.

The restrictive nature of forced collaboration prevented the teachers from achieving tasks and goals that they considered pertinent to their classroom needs. While the structured agenda provided a format for addressing critical topics such as curriculum, instruction, and assessment, the categories were broad, with little clarity on what type of discussions qualified for each item.

When the administration did not provide specific topics for each agenda item, the teachers expressed frustration and confusion regarding the expectations for the meeting. Often, the teachers expressed frustration over the need to address more important issues that were not permitted within the PLC meeting. These findings are consistent with the argument presented by Stoll and Louis (2007) that professional learning communities are not designed to be dependent upon an authority figure such as a principal. Instead, they are intended to be a location of collective learning. Stoll and Louis explain that:

> [W]hen PLCs are merely devices for implementing external pressures for greater tested results, the frantic rush to produce the right numbers that will appease outside authorities, drains teachers' passion and energy, and eventually undermines the essential human resource on which sustainable educational improvement depends (p. 191).

The researcher found this analysis to be consistent throughout all PLC meetings that occurred during this study. Moments of enthusiasm and passion were observed only between the agenda items as teachers discussed issues that were of specific interest to their current classroom situations.

Through a social constructivist lens (Vygotsky, 1978), this study found that interactions among members of the community of practice (Lave & Wenger, 1991) enabled the individuals to construct meaning out of the issues that they faced as science teachers. While the PLC provided a location for sociocultural interactions, the day-to-day exchanges that occurred between the teachers proved to be invaluable. Collaboration that occurred without administrative directives, unforced collaboration, originated out of necessity and was found to be tailored more to the needs of the teachers. Most unforced collaboration occurred in the third space (Moje, Ciechanowski, Dramer, Ellis, Carrillo, & Collazo, 2004) including times and spaces not designated as meeting locations. In particular, these conversations occurred during breakfast duty, lunch break, in the hallway between classes, and when necessary, during planning periods and after school. In concurrence with Moje et al's study conducted on the use of third space to teach science content, third space was found to be a location for the development of multiple forms of knowledge and collaborative discourse. More specifically, the third space was an area for science teachers to share ideas, develop lessons, and learn from one another as they each negotiated meaning through social interaction within the community of practice (Lave & Wenger, 1991). When necessary, a formal meeting time and location would be established to accomplish a task that required more time. Unforced collaboration was found to be self-regulated, cordial, and purposeful, focusing only on issues that the teachers considered important. It was found that the majority of time utilized for unforced collaboration was shared with additional tasks such as monitoring students in the cafeteria or hallway, grading papers, or making copies. Evidence of shared time was also seen in during the PLC, as the teachers used moments between agenda tasks to discuss issues such as content and classroom management. This allowed teachers to make the most of every available minute throughout the day and ensure that times allotted for planning could be used to set up laboratory experiments, grade assignments, and prepare for class.

Teacher identity. Data analysis consistently demonstrated that teacher identity was a key aspect to understanding the culture of science education in both *identity formation and negotiation* and in *comparisons across the community.* Findings indicated that characteristics and behaviors developed through involvement in other communities of practice were transferred to help form the science teachers' unique identities. The teacher's identity was also found to influence interactions that occurred in the classroom. Even when lesson plans were identical, the researcher noted that lessons did not seem to provide identical experiences when taught by different teachers.

From data analysis, the formation and negotiability of teacher identity was shown to involve a mosaic of experiences resulting in each teacher developing his/her unique identity. Aspects of a teacher's identity were derived from the various behaviors and practices that allowed him/her to be successful within a given community. Experiences found to contribute to teachers' identities were participation in various careers before becoming a teacher, participation as a student in science classes, and other activities that took place both inside and outside of the school. Using a social constructivist (Vygotsky, 1978), this study found that characteristics of a teacher's identity were revealed through the actions and interactions that he/she had in the classroom and when interacting with colleagues. Hewson (2007) presented similar findings in his reflection of going from a physicist to a science educator. He explains that many different events and the careers throughout his life had an impact on his career as a science educator. He concluded that:

> Another way of characterizing my professional career is in terms of the different communities with which I have been associated... While there clearly is an individual, cognitive character to our learning, we are also social, cultural, affective creatures who respond to those around us in a variety of ways that are strongly influential of the questions we ask, the opinions we espouse, and the understandings we create... I can now affirm how essential community has been to my personal growth (p. 131)

In comparisons across the community of practice, it was found that meanings that were developed within a variety of life experiences were negotiated as part of each teacher's unique identity and had an impact on the type of teacher that he/she was in the classroom. Data analysis also found that behaviors that individual teachers identified as being useful in teaching science were negotiated as part of his/her teaching identity. Through the dual process of identification and negotiability (Wenger, 1998), science teachers developed views of what it means to be a good teacher and then translate those views into the type of teacher they were in the classroom. Even when lesson plans and teaching styles were similar, the engagement and interactions with students in the classroom varied providing a learning experience that was characteristic of that teacher's unique identity.

Mandated policies. The culture of science education was found to incorporate multiple factors that were outside of the teachers' control. For the purpose of this study, these aspects were referred to as mandated policies. Categories associated with this theme included curriculum standards, state and local regulations, and high-stakes testing. Domains that supported this theme included: (1) *teaching the standards and preparing for standardized tests,* (2) *addressing the added requirements*, and (3) *responses and repercussions*. Findings from this investigation support the fact that such policies can result in teacher burnout and other stress-related illness in teachers (Borman & Dowling, 2008; Brown, Ralph, & Brember, 2002; Halim,Samsudin, Meerah, & Osman, 2006; Harris, Halpin, & Halpin, 1985; Jepson & Forrest, 2006). This study looks at mandated policies as an aspect of their culture that they must persevere and analyzes the influence these policies had on the social interactions and daily activities of the teachers.

Teaching the standards and preparing for standardized tests were top priority when developing curriculum maps and lesson plans. The purpose of curriculum maps was to ensure adequate time was set aside to cover all standards prior to the test. With the expanse of content required for each course, the curriculum map left little room for deviation or embellishment. Teachers expressed frustration about the limited amount of time to cover all of the standards, arguing that everything was so compact that they were unable to incorporate topics that they felt would be beneficial for the next course in sequence or that would be of interest to the students.

In addition to teaching the standards, the school administrative team, partly in response to state recommendations, had established additional requirements for teachers to follow. These added requirements came in the form of pedagogical strategies, daily routines to maintain consistency across all classes, and general lesson formats. Findings suggest that teachers were not receptive to any policy that hindered the effective teaching of their lessons. Whether the teachers chose to implement the strategies or policies depended heavily on how well it fit with what they were already doing. This resulted in teachers having to defend reasons for not incorporating various strategies. “Where power is exercised, so too resistance can be found” (Blades, 1997, p. 218). The teachers were resistant to anything that did not align with their beliefs about how science should be taught or with what they found to work in their classrooms. Findings support the argument Rodriguez (2010) presents that policies mandated at both state and district levels without regard for the teachers’ professional knowledge can have negative consequences. He offers that policies implemented without regard for science teachers’ unique working contexts or progress in professional development had a tendency to be oppressive and regressive in nature, having a negative impact on student learning.

Teachers responded to these demands in two ways. First of all, they refused to be absent, working even when they were sick. They also spent large amounts of time beyond the required work day in addition to taking work home to grade. Findings suggest a great deal of self-sacrifice on the part of the science teachers to ensure that students were provided every opportunity to learn the standards. When new policies were established, the teachers used their own judgment to determine if the strategy would be applied in their classrooms. For example, tiered differentiated instruction was attempted in one class and found to be less beneficial than guided practice, so the teacher refused to utilize a strategy that did not provide students with the necessary skills and content to pass the test.

Findings were significant to understanding the culture of science education because each theme represented a fundamental aspect of the culture that enabled teachers to determine the best approach to teaching their students. The social interactions within this culture provided for teacher needs in the areas of classroom management, content knowledge, and collegial support. From a social constructivist (Vygotsky, 1978; Wertsch, 1998), it was found that science teachers learn from experience in social situations, including collaboration within the community of practice (Lave & Wenger, 1991) and interactions on the path to becoming a teacher that form their teacher identity (Gee, 2001), that allow teachers to make meaning of what it is to be a successful science teacher and to survive within the culture of science education.

How Does the Culture of Science Education Inform Teacher Practice?

In response to the second research question, data analysis revealed that the culture of science education informed teacher practice in two key areas: (1) *instructional method*, and (2) *laboratory work*. Collaboration with colleagues, teacher identity, and policies mandated by the state and local school administration all influenced choices that the teachers made in their classrooms. First of all, it influenced the type of instruction used to teach the standards and ensure that students were prepared for standardized tests. Secondly, the use of laboratory work in the science class was considered a high priority. However, the depth of inquiry allowed for lab work was impacted by various constraints that were out of the teachers' control.

Instructional method. This investigation found that aspects of the culture of science education had a strong impact on instructional method used in the classroom. Domains that supported the theme of instructional method included: *using what works*, *sharing ideas*, and *perceived autonomy*. In each instance, the science teachers chose pedagogical strategies that they felt were the most efficient means of covering the standards and ensuring student success on standardized tests.

Teachers in this study were very adamant about using what they found to work in their classrooms. The use of direct instruction, guided practice, and laboratory work dominated the lesson plans. There were a few instances of cooperative group learning, but these strategies were used only when the science concept did not lend itself to laboratory work. These topics were referred to as “dry chapters,” or content chapters that contained no labs that bolstered the content. Ensuring that students had numerous opportunities to experience laboratory work was a great priority, yet they did not incorporate a lab unless it had a purpose that supported the content. Organizational strategies such as guided notes, foldables, and notebooks were used in conjunction with lectures and lab activities.

The sharing of ideas throughout the community of practice (Lave & Wenger, 1991) was the effective way of ensuring the application of new pedagogical strategies. The teachers explained that they learned a lot from observing and listening to their colleagues, both in the science department and in other departments throughout the school. Through various sociocultural interactions (Vygotsky, 1978), ideas were shared for teaching content, managing classroom routines, and implementing new strategies. Collaboration extended beyond the school to include colleagues from other school systems and university faculty. When a strategy was shared by a colleague who had used it successfully in their own classroom, the teachers were more likely to try it themselves than if the administration prompted the demand for its use.

When asked to share their thoughts on autonomy, the participants stated that they had a great deal of autonomy when it came to choosing their approach to teaching science, yet they continually reflected that their reasons for choosing direct instruction were centered on the necessity to cover all standards in time for state-mandated tests. These findings support a study by Wideen, O'Shea, and Ivy (1997) that while decisions for instruction were left primarily in the hands of the schools and teachers, most teachers felt there was little flexibility when high-stakes tests were in place. They concluded that these examinations "undermined the notion of teacher as autonomous professional" (p. 440). Au (2007) determined that a significant number of qualitative studies pinpoint high-stakes tests as a major contributor to the increase in the use of teacher-centered strategies such as direct instruction. Similarly, Wallace (2012) argued that "Under curriculum structures that emphasize content and product, pedagogy becomes less diverse, less contextualized, and less creative as teachers are urged to teach the same material the same way" (p. 301). The findings of this study parallel these additional studies, but the distinct difference noted in this investigation was that the participants perceived that there was a great deal of autonomy in their approach to teaching science. Statements regarding their perception of autonomy were contradicted by expressions of concern that other methods of instruction limit the amount of content covered before the test.

Laboratory work. Next to direct instruction, laboratory work was found to be one of the most crucial aspects of teaching science. All teachers in this study felt strongly that students should have authentic laboratory experiences, and that they should be in the lab often. The two domains that supported the emergence of this theme included: *frequency of laboratory work* and *depth of inquiry*. While teachers held strong beliefs about the importance of the laboratory, there were other factors within the culture of science education that determined the degree to which laboratory work was included throughout the curriculum. The teachers felt that the state had an "unrealistic perception" [I, 69] about how much inquiry science teachers could incorporate and still cover all required standards. The values and beliefs associated with the use of inquiry were constructed through sociocultural interactions (Vygotsky, 1978) with fellow science teachers and respected mentors and professors who provided a more “realistic attitude” [I, 30] associated with laboratory work. The primary concern for both the frequency of laboratory work and the depth of inquiry was related to the lack of time to incorporate more robust activities. While the average number of labs varied from one class to the next, the general consensus was that lab was an essential component of science teaching. Also, each teacher expressed the importance of using inquiry in the lab, but in the same respect, they were unable to do so because of time constraints and the demand to cover large quantities of information before the tests. When using inquiry, it was always in the form of guided inquiry. This allowed the teacher to ensure that students derived the same intended concepts. Carlone, Haun-Frank, and Kimmel (2010) found similar concerns regarding time needed to teach inquiry activities emerged from constraints associated with institutional policies and structures such as preparation for standardized tests. These restrictions prohibit the ability of science teachers to provide laboratory experiences that are truly authentic. Galison (1997) explains that the culture of the laboratory draws on more than just sharing objects and traditions; that it is also about “establishment of new patterns and their use” (p. 52). As long as science education is bounded with standardized tests guarding the perimeter, experiences in the classroom laboratory will remain limited to mere snippets of scientific practices that address a predetermined curriculum.

Implications

This investigation sought to better understand the culture of science education and how this culture informs teacher practice. From data analysis, the study found aspects that help define the culture of science education to include the collaboration among science educators, the formation and negotiation of science teacher identity, and the influence of mandated policies. These factors inform teacher practice in the science classroom in both teachers' choice of instructional methods and in the limited use of inquiry-based laboratory activities.

The results of this study have implications for secondary science teaching. While the study focused on four science teachers in a small rural high school, the findings are significant for all science teachers experiencing the demands to ensure students perform well on high-stakes tests. The following sections include implications for practice, for teacher education and professional development, and for research in science teaching.

Implications for Practice

From this study, there were several implications for teacher practice. While control over standardized tests and curriculum standards remain largely out of the teacher's control, it was through the supportive and collaborative nature of the community of practice (Lave & Wenger, 1991) that teachers in this study found strength. Teaching within the community of practice was a team effort. While each teacher maintained his/her own strengths and expertise, they learned from one another, both by conferring with one another on questions of content and through other social interactions (Vygotsky, 1978).

Further study in the area of teacher practice could involve applying a similar study to a larger group of teachers. The context of this study was a small rural high school in which no more than two teachers were teaching the same content course. In larger schools, it would be interesting to see how groups greater than two collaborate for the same course. A second suggestion for further study would be to follow one of these teachers into a new school setting and see if the themes established for the culture of science education hold true for that teacher and how his/her identity is shaped further by the transference of meanings established in this school to the negotiability of those meanings within the new context.

Implications for Teacher Education and Professional Development

This study found that each teacher maintained a unique teacher identity that was developed through multiple experiences both on the path to becoming a science teacher and while teaching science. Individual teacher identities incorporate behaviors and characteristics that each teacher considered valuable to being successful within a given community of practice (Lave & Wenger, 1991). To ensure that teachers gain authentic science experiences in route to becoming a teacher, it is necessary for teacher education programs to incorporate these through adequate numbers of science content courses in the program of study and through science methods and other similar classes that provide an opportunity for students to experience science in a more teacher-centered approach.

Secondly, this study found that the science teachers did not always value the professional development provided to them, expressing that some forms of professional development were useless and time consuming. One teacher even attempted to use a strategy pushed through professional development to all teachers in the school. After attempting the activity with her students, she found that scores on the tests dropped significantly from previous semesters when guided practice was used to teach the concept. Professional development was more valuable to the group when they saw the immediate significance for their classrooms.

Suggestions for further study related to teacher education and professional development involve long term case studies to see how new teachers implement the strategies presented in their education classes. Additionally, studies could be done to evaluate the implementation and success of staff development from the perspective of the science teacher. It would be interesting to see which aspects of the culture of science education determine which professional developments are incorporated into the lesson plans and why.

Implications for Curriculum Studies

The importance of this study to the field of curriculum studies lies in understanding the system of forced relationships and procedures of power (Blades, 1997) that persuaded these teachers to sacrifice their own time and well-being to ensure that students were able to succeed on the tests. Aspects of the culture of science education contribute to the oppression of science teachers through demands to address all standards within the constraints of the school and state mandated policies. Freire (2000) expressed that, "For the oppressors, what is worthwhile is to have more—always more—even at the cost of the oppressed having less or having nothing." (p. 58). The sacrifices made by science teachers to ensure student success seemed to never be enough. There was always going to be one more policy, one more mandate to control what teachers were doing in the classroom.

Suggestions for further study in the area of curriculum studies would be to take a deeper look at the life and experiences of the teachers within the community. Taking a profound look at the narrative that emerges from a single teacher's story reveals a more intimate connection between the teacher and his/her interactions with individuals and communities that influenced the teacher he/she has become. Secondly, the collaborative efforts made between teachers who were teaching the same content course was done voluntarily. Upon a follow-up visit, it was discovered that the school had taken this idea and developed a school-wide mandate that any teachers who were teaching the same course must follow new regulations for planning the courses together. It would be interesting to see how this new policy affects the unforced collaboration that was already in place.

Implications for Research

Suggestions for expanding this study include performing a longitudinal study that would follow participants throughout their career. At the time of this study, the science standards were in place and curriculum maps were already written. A longitudinal study would provide an opportunity to observe the implementation of the Next Generation Science Standards and evaluated the impact that major changes in policy hold for science teachers as they adapt to new curricula. As the study was concluded, one of the science teachers left the high school to begin teaching at a middle school in an adjacent county. A longitudinal study was also provide an opportunity to see how new teachers learn to become accepted as a member of the community of practice (Lave & Wenger, 1991). It would be interesting to follow up on his transition from the community of practice (Lave & Wenger) in this study to a new community with teachers of differing backgrounds and perspectives. A second suggestion for further research takes this study to a larger school. The case used for this study was within the context of a small rural high school where each teacher within the community was viewed as an expert in his or her field of science. Science teachers in this study held a high degree of respect for their colleagues. It would be interesting to see how this compares to schools where multiple teachers are responsible for the same content.

Implications for Policy

Science teachers in this study were required to respond to policies mandated at the local, state, and federal level. Professional learning opportunities were provided for teachers on a school level, and all teachers were expected to implement the required strategies presented. The science teachers in this study worked late hours, took work home over the weekend, and even worked while they were sick to ensure that all standards were covered in time for standardized tests. When a policy or mandated strategy did not enhance the ability to cover standards in an effective and timely manner, the strategy was abandoned. However, there was still a concern that there would be consequences for not following policy. In some cases, the strategies were incorporated in written lesson plans, but were not a complete reflection of what was implemented in the classroom. These types of mandated policies result in increased stress for the teachers.

Implications for policy include providing teachers with individualized professional development that meets the pedagogical needs of that particular teacher and the goals of his or her department. Further study in this area could look at teachers' attitudes and willingness to attempt and continue using a strategy that was selected by the teacher instead of required by administration.

Conclusions

The purpose of this study was to define the culture of science education and to investigate how this culture informs teacher practice in the science classroom. Consistent patterns of analysis found five themes that emerged in response to these two questions. The themes include: (1) *constant collaboration*, (2) *teacher identity,* (3) *mandated policies,* (4) *instructional method,* and (5) *laboratory work.* These themes provided a framework for understanding the social interactions that occurred within the community of practice (Lave & Wenger, 1991). Through the use of a social constructivist (Vygotsky, 1978; Wertsch, 1985) and an ethnographic (Denzin & Lincoln, 2003; Geertz, 1973; Goodenough, 1970, 1981; Lincoln & Guba, 1985; Merriam, 1990; Stake, 1995) perspective, the researcher was able to describe the day-to-day influences that impacted the lives of science teachers within the culture of science education.

Throughout data collection, the teachers continually reiterated that the most important aspect of science education was the students. The dedication and self-sacrifice was done, not to appease the state or school administration, but for the students, to ensure that they could, not only pass the test, but also be prepared for the next phase of their lives. Ruth expressed this sentiment in one of her interviews, and it seems appropriate to conclude this investigation with this reminder.

Ruth: Teaching is more than just imparting information. It’s taking care of people, too. It’s also setting examples for kids. You have to be conscious of all these little minds; all these eyes that are watching everything you do, listening to everything you say, and in some cases, taking it, and putting it... pieces of you become pieces of them.

[I, 17]

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