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Practices, Beliefs, And Perceptions Of Effective Science Teachers In Elementary Schools Serving Low Socioeconomic Communities

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PRACTICES, BELIEFS, AND PERCEPTIONS OF EFFECTIVE SCIENCE
TEACHERS IN ELEMENTARY SCHOOLS SERVING LOW SOCIOECONOMIC
COMMUNITIES

by

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DEDICATION

To all of the students who strive to do the best they can under circumstances beyond their control and yet still manage to develop an excitement for the natural world and a love for science. And to all of the hard working teachers who see the greatness in all of their young scientists, no matter who they are or from whence they have come, and who help foster that excitement for the natural world and that love for science.

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To the participating teachers and their students, thank you very much for allowing me to be a part of your classes on those days you invited me in to see the very best you had to offer. And to the principals at those schools, thank you for allowing me to partner with some truly wonderful teachers.

And finally, to my wonderful wife Lauren and my boys Edwin and Ian, thank you for your patience, understanding, and willingness to allow me to conduct this research between our many swim meets, cello practices, fencing club sessions, Boy Scout outings, and weekend movies. I could never have done this without your support.

ABSTRACT

Students who come from low socioeconomic status (SES) backgrounds are more likely to manifest a science achievement gap when compared to their high SES peers as a result of the myriad of factors that have the potential to influence student performance, including limited access to resources, fewer life experiences, health care concerns, fewer extracurricular opportunities, etc. (Crook & Evans, 2014; Duke, 2000; Ladd, 2012; Sirin, 2005). This achievement gap can be exacerbated in the elementary setting where many teachers do not feel comfortable teaching science as a result of a lack of science content knowledge and limited experience teaching inquiry-based science (Akerson, et. al., 2009; Diaconu, Radigan, Suskavcevic, & Nichol, 2012; Ricketts, 2014; Sandholtz & Ringstaff, 2013). These challenges are further compounded as a result of systemic barriers to effective science instruction at the elementary level that stem from a prioritization on literacy and math as well as a focus on high stakes testing in those content areas, especially at schools that are already underperforming (Gutierrez, 2015; Johnson & Fargo, 2014; Mensah, 2010; Sandholtz & Ringstaff, 2013). Despite these challenges, there are students in low SES schools that are reducing the science achievement gap. After studying the instructional practices, pedagogical methods, attitudes, and beliefs of three 4th grade teachers in three different suburban schools in a southeastern state whose low SES students show a smaller achievement gap compared to their higher SES counterparts across the school district, it was found that these teachers

employed a combination of science inquiry and culturally relevant practices and pedagogies that might account for the success of their students. These included a focus on student understanding over rote memorization of facts, the use of authentic hands-on science practices to develop conceptual understanding, and the fostering of a social learning community. Furthermore, not only did these teachers display a positive mindset with regard to teaching science and the capabilities of their students, many of the students of these teachers expressed positive attitudes about their teacher and about learning science, as well as a feeling that their teacher believed in them as young scientists and learners.

PREFACE

The basis for this research emerged as a result of my participation in many school data meetings. While these data discussions focused on different demographic groups, including student ethnicity, gender, language, and special needs status, seldom did these conversations target indicators of poverty related to achievement outcomes. Additionally, while science achievement was a part of the overall conversation in these data meetings, it was never discussed in the context of any demographic subgroup.

As I began to look at this phenomenon across the state in which I live, I discovered that there is a discernable gap between students identified as living in poverty and those who were identified as not living in poverty in terms of those who met or exceeded performance expectations on the state's end of the year elementary and middle school standardized science test. This was made all the more troubling for me when I determined that across the entire state nearly 60% of those elementary and middle school test-takers were identified as living in poverty. There was a conversation to be had that not many people were having.

In my experiences working with elementary teachers, I have observed young learners accomplishing extraordinary things in science, including in schools that serve low socioeconomic communities. Despite the challenges to success that are often associated with poverty, students are succeeding. What I want to know is what those teachers and students are doing that might account for that success against the odds.

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LIST OF ABBREVIATIONS

CRP	Culturally Relevant Pedagogy
ELA.....	English Language Arts
ELL	English Language Learners
IPL-S	Instructional Practices Log- Science
K-5	Kindergarten through 5 th grade
NAEP	National Assessment of Educational Progress
NRC	National Research Council
NSLP.....	National School Lunch Program
PD	Professional Development
SEP.....	Science and Engineering Practice
SES.....	Socioeconomic Status
SIP.....	Students in Poverty

CHAPTER 1

INTRODUCTION

Among recent reform efforts in K-12 science education, there has been a call for a shift from didactic, content-centric instructional practices to practices that engage students in the process of constructing scientific understandings through scientific inquiry (Berland & Reiser, 2008; Hokayem & Schwarz, 2014; Songer & Gotwals, 2012; Wu & Hsieh, 2006). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012), a document that has been instrumental in the development of the Next Generation Science Standards (NGSS Lead States, 2013) as well as state standards, such as the *South Carolina Academic Standards and Performance Indicators for Science* (SCDE, 2014), describes science education as learning core disciplinary science content through the application of science and engineering practices. This document argues that it is necessary to engage students in learning science through these authentic practices to address the tension between science as a body of knowledge versus science as a collection of practices, asserting that a “narrow focus on content alone has the unfortunate consequence of leaving students with naïve conceptions of the nature of science inquiry and the impression that science is simply a body of isolated facts” (NRC, 2012, p. 41).

At the same time as the *Framework* calls for a practices-based approach to science education, it also calls for greater equity in science and engineering learning, espousing the idea that one of the major goals of science education should be to provide

all students, regardless of socioeconomic status or ethnicity, with the skills to be successful in science and engineering learning, particularly in the context of one's own personal and community priorities (NRC, 2012). However, despite this call for equity in science education, there persists a significant science achievement gap across a variety of demographic groups, including ethnicity, language, and poverty (Curran & Kellogg, 2016; NRC, 2012; Noble, Rosebery, Suarze, Warren, & O'Connor, 2014; Vijil, Slate, & Combes, 2012).

Current studies into effective science instructional practices in high poverty schools can give some insight into what works in helping low socioeconomic status (SES) students overcome the science achievement gap. In examining these practices, the different approaches employed by teachers to close the achievement gap in science in low SES schools largely draw from one of two differing theoretical frameworks. One approach looks at the solution to the problem of the achievement gap in science where reform-based science inquiry practices are used to level the playing field for students by providing all learners in the class with a common set of experiences that form the foundation for knowledge-constructing to occur (Geier, et. al., 2008; Jackson & Ash, 2012; Johnson, 2009; Shaw & Nagashima, 2009). In this way, the teacher's approach draws from a constructivist framework whereby new knowledge is created through experience and social interaction, in this case the investigation of natural phenomenon through the use of authentic science practices executed through collaborative student learning. In addition to research that examines the potential for science inquiry practices to help close this achievement gap, studies have also examined the capacity for culturally relevant instructional practices to improve science achievement in low SES settings.

Though this lens, teachers recognize and honor the cultural differences that might exist within the classroom and empower students to use their strengths and interests to make connections with the science content (Grimberg & Gummer, 2013; Ladson-Billings, 1995; Laughler & Adams, 2012; Lee, 2004). Two key elements of culturally relevant pedagogy (CRP) that are congruent with the assertions described in the NRC *Framework* are that knowledge is a fluid, evolving thing that is constructed through experience and interaction and that all students are capable of learning science, regardless of who they are (Ladson-Billings, 1995; NRC, 2012). Additionally, students engaged in a culturally relevant learning environment will be challenged to not only examine the nature of scientific knowledge, but to consider its value and relevance with regard to themselves and their community (Ladson-Billings, 1995).

BACKGROUND OF THE PROBLEM

Various studies have examined the science achievement gap phenomenon through the lens of ethnicity and language. In one study researchers noted that, despite showing evidence of understanding science concepts aligned to the state standards, a group of 5th grade English Language Learner (ELL) students performed poorly on assessment items compared with their non-ELL counterparts (Noble, Rosebery, Suarze, Warren, & O'Connor, 2014). In Texas, White students outperformed Hispanic students in grades 5, 8, and 11 over a three-year period of study (Vijil, Slate, & Combes, 2012). Further evidence of this ethnicity-based achievement gap exists as young as Kindergarten and first grade, where large gaps between African-American and White and Hispanic and White students were present (Curran & Kellogg, 2016). While these studies have identified the existence of the achievement gap in science relative to ethnicity or

language, there have been few studies that have examined this achievement gap as an issue of poverty.

In public schools in the southeastern state where this study takes place, starting with the 2017-2018 school year, science performance is assessed at the end of grades four, six, and eight by means of a state administered summative standardized assessment. In reporting data from the test, the state's Department of Education provides a school district level breakdown of grade level assessment results by different demographic groups. Table 1.1 presents the statewide results of this assessment for the 2016-2017 school year (SCDE, 2017). During the 2016-2017 school year, the last year for which all students in all grades 4 through 8 were tested in science, the overall state performance for students in grades 4 through 8 who scored a rating of "Meet Expectations" or "Exceeds Expectations" ranged from 46.1% to 49.5%. However, the performance for Students in Poverty (SIP) who scored "Meet Expectations" or "Exceeds Expectations" across the state ranged from 32.9% to 36.3%. In contrast, Non-SIP statewide performance for "Meet Expectations" or "Exceeds Expectations" ranged from 65.1% to 68.9%. The data show how across all five assessed grades Non-SIP significantly outperformed their SIP counterparts. Given that 59.3% of the students in grade 4 through 8 taking this test in 2015 were identified as SIP compared with 40.7% of grade 4 through 8 being Non-SIP students, this highlights a significant gap in science achievement for the SIP demographic. In contrast to the percentage of state-wide test takers who were identified as SIP, 42.3% of the grade 4 through 8 students who took the state science assessment in 2017 were identified as African-American or Hispanic, two demographic groups typically examined in studies that look at achievement gaps in different content areas.

Table 1.1 2017 Statewide Science Results for of Students Scoring “Meets Expectations” or “Exceed Expectations”

Grade	N	Percentage of Students scoring “Meet Expectations” or “Exceeds Expectations” on the 2017 Science Test
Grade 4 (All)	60278	48.4.
Grade 4 (Non-SIP)	22288	68.9
Grade 4 (SIP)	37758	36.3
Grade 5 (All)	57902	46.1
Grade 5 (Non-SIP)	22663	66.2
Grade 5 (SIP)	35026	33.3
Grade 6 (All)	56534	48.0
Grade 6 (Non-SIP)	23058	67.9
Grade 6 (SIP)	33270	34.3
Grade 7 (All)	56050	46.5
Grade 7 (Non-SIP)	23708	65.1
Grade 7 (SIP)	32148	32.9
Grade 8 (All)	55226	49.5
Grade 8 (Non-SIP)	24366	68.2
Grade 8 (SIP)	30680	34.9

While issues of poverty are often connected with ethnicity, the higher percentage of students test takers identified as SIP relative to those in traditionally underrepresented ethnicities suggests that the issue of poverty as it pertains to the science achievement gap in this particular state transcends ethnicity to some degree.

High SES vs. Low SES Schools.

Numerous studies suggest that one major source for this socioeconomic achievement gap is related to the inequities that exist between families of high SES and families of low SES. High SES families are more likely to provide stimulating learning materials, have access to better healthcare, and provide a more language-rich environment when compared with students from low SES families (Berliner, 2006; Crook & Evans, 2014; Garcy, 2009; Holliday, Cimetta, Cutshaw, Yaden, & Marx, 2014; Shields, Walsh, & Lee-St. John, 2016). Additionally, students living in poverty are less likely than their more affluent counterparts to have access to a wide variety of resources or life experiences (Dearing et. al., 2016; Ladd, 2012; Morgan, Farkas, Hillemeirer, & Maczuga, 2016; Sirin, 2005). This can set students from low SES backgrounds at a disadvantage when entering school, especially in a more traditional, didactic, teacher-centric academic setting where direct instruction methods more often support students who already come to class armed with knowledge and experiences related to the content (NRC, 2012).

In addition to the disparities that exist between students from different economic circumstances, the socioeconomic setting of the school itself can also have an impact on the quality of instruction that takes place, especially with regard to elementary science. Schools serving low SES neighborhoods are more likely faced with reduced funding (Gorard, 2016; Lee, 2012; Sirin, 2005). This can result in students from low SES neighborhoods attending underperforming schools that typically have a harder time recruiting and retaining high quality or experienced teachers and staff, especially in critical need areas such as science and mathematics. (Clotfelter, Ladd, & Vigdor, 2010;

Hani, 2012; Johnson, Kahle, & Fargo, 2007; Lee, 2012). Furthermore, schools serving low SES communities more likely to contend with a lack of up-to-date resources and materials, again especially in math and science (Balfanz & Byrnes, 2006; Gorard, 2016; Sirin 2005).

Science Inquiry in the Elementary Setting.

In addition to the problems of teacher quality and access to resources in high poverty schools, elementary schools in particular also face systemic challenges to enacting effective, inquiry-focused science instruction (Mensah, 2010; Sandholtz & Ringstaff, 2013). Elementary teachers typically have an inaccurate or incomplete understanding of science inquiry (Akerson, et. al., 2009; Kim & King, 2012; NRC, 2012; Ricketts, 2014). Furthermore, since elementary teachers are more or less generalists with little to no formal science background training, most have very limited science content knowledge (Sandholtz & Ringstaff, 2013; Sherman & MacDonald, 2008; Slavin, Lake, Hanley, & Thurston, 2014; Thomson & Kaufmann, 2013). Elementary schools are also more likely to allocate their resources, time, and efforts towards English language arts (ELA) and mathematics, resulting in science instruction being marginalized, if it is taught at all (Johnson & Fargo, 2014; Sherman & MacDonald, 2008; Slavin, Lake, Hanley, & Thurston, 2014; Thomson & Kaufmann, 2013). Given the challenges faced by schools serving low SES communities in terms of recruiting and retaining highly qualified teachers as well as in supporting teachers with up to date, rigorous materials and resources, the likelihood that elementary teachers lack accurate science conceptual content knowledge, have limited experience with science inquiry practices, and are faced with pressures to prioritize subjects other than science make it all the more difficult to

provide high quality, rigorous, inquiry-focused science teaching in high poverty elementary schools (Adamson, Santau, & Lee, 2012; Diaconu, Radigan, Suskavcevic, & Nichol, 2012; Johnson & Fargo, 2014). These challenges of dedicating instructional time, focus, and resources to quality science instruction, in turn, can impact negatively student achievement, in particular in schools serving low SES communities (Blank, 2013).

STATEMENT OF THE PROBLEM

There is a persistent achievement gap in science between students from less diverse backgrounds and students who come from different racial/ethnic, cultural, linguistic, and socioeconomic backgrounds (Geier, et. al., 2008; Johnson, 2009; Lee, 2005). Despite this, there is a lack of research into the nature of the achievement gaps in science or how to help non-mainstream students overcome them (Geier, et. al., 2008; Lee, 2005). Furthermore, the research that has been conducted tends to consider the achievement gap primarily through the lens of ethnicity or language as factors related to socioeconomic status rather than looking at the science achievement gap primarily through the lens of poverty. What research there is into effective instructional approaches to combat the achievement gap for non-mainstream students often examines the problem from two different theoretical frameworks: inquiry-based science learning and CRP. Despite the calls of science reform advocates for a shift from a didactic, teacher-centric behaviorist approach to a constructivist, inquiry-focused approach as well as for the need for science to be more inclusive in nature, the continued presence of this achievement gap suggests that there is still much work to be done in identifying the root causes of the science achievement gap as well as in identifying practices and pedagogies that are effective at combatting it.

PURPOSE OF THE STUDY

The purpose of this descriptive study is to identify teachers in schools serving low SES neighborhoods whose students are performing above the average when compared with other students identified as living in poverty and to determine what instructional practices and pedagogical approaches are being employed in these classes that might be responsible for the students narrowing the achievement gap in science, as well as what beliefs underlie and inform the instructional decisions of these teachers.

RESEARCH QUESTIONS

The following research questions informed the researcher's process of identifying, describing, and analyzing classroom practices, pedagogical approaches, beliefs, and impacts of highly effective elementary science teachers in schools serving low SES communities:

- What are the instructional practices being employed by elementary teachers in classrooms where the science achievement gap is less than predicted by school and district test data?
- To what degree do the instructional practices being employed by these elementary teachers reflect inquiry teaching practices and/or culturally relevant teaching practices with the potential to reduce the achievement gap in science?
- What do teachers feel are their most influential beliefs and experiences regarding teaching and learning science of elementary teachers in classrooms where the science achievement gap is less than predicted by school and district test data?
- What are the perceptions regarding learning science among the students of teachers who are successful at reducing the elementary science achievement gap?

SIGNIFICANCE OF THE STUDY

In light of the persistent science achievement gap, there is a clear need to identify practices employed by teachers that have been successful at reducing this achievement gap for their students with regard to poverty. Additionally, because culturally relevant pedagogies and constructivist science inquiry practices are not mutually exclusive and, in fact, are congruent in the manner by which they define knowledge as a thing constructed by the students through their experiences and interactions, it is necessary to determine the degree to which successful science teachers employ the instructional practices of one or the other or both of these theoretical frameworks.

The significance of this study will be to add to the body of knowledge about the beliefs and instructional practices that elementary teachers might employ that have the potential to reduce the science achievement gap. In so doing, this information can help support school, district, and university efforts at preparing teachers to successfully engage an increasingly diverse student population in the process of learning science in alignment with the directives of current science teaching reform efforts and culturally relevant instructional practices. Insights developed from this study can be used to design professional development programs as well as university science methods course work to better prepare teachers to help all of their students be successful in learning science.

DEFINITIONS OF TERMS

- Science practices: Science practices are defined in *A Framework for K-12 Science Education* (NRC, 2012) as a combination of authentic practices that scientists engage in as a matter of routine work. It is through the application of these practices that science knowledge is constructed through the investigation of

natural phenomena that lead ultimately to the establishment of new or refined scientific explanations.

- **Inquiry-focus teaching:** In the context of this study, the term inquiry-focused teaching refers to a learning process whereby students are engaged in experiential learning where, through the application of authentic science practices, scientific knowledge building occurs in which students use evidence (both provided and experientially derived) and scientific reasoning to support claims and construct explanations about natural phenomena. Scientific inquiry also involves the communication of the students' constructed knowledge and supporting evidence and reasoning through explanations construction, argumentation, and the development and use of scientific models.
- **Constructivism:** A constructivist framework defines learning as a process through which students build knowledge through experiential learning and social interactions as new experiences cause students to challenge older knowledge. In the constructivist framework authenticity helps provide legitimacy to the learning by demonstrating why it is necessary to challenge established understandings with new ones (Chiatula, 2015; Faircloth & Miller, 2011; Tippett, 2009; Vygotsky, 1978).
- **Culturally relevant pedagogy (CRP):** Culturally relevant pedagogy takes into account the cultural identities of the students in the teacher's class as well as what their culture prioritizes. Explicit efforts to connect content and concepts with ideas, activities, and events that are important to the unique cultural identity of the students are essential to implementing successful culturally relevant instruction

that results in student achievement. At the same time, it is important that the teacher holds a view of the students as capable learners whose cultural identities are a source of strength to the learning and not an impediment (Ladson-Billings, 1995; Laughter & Adams, 2012).

- Socioeconomic status (SES): Socioeconomic status in this context is used to describe the characteristics of an individual, group, or setting that reflects the social and economic conditions that are impacted by the income level of the individuals in the represented group.
- Poverty: In the context of this study, poverty primarily refers to individuals who qualify for free or reduced lunch status under the federal school lunch program based on their family's income status. Because participation in the federal free or reduced lunch program depends on one's family income status and is reported to schools, it can serve as a consistent marker for poverty that can allow for comparison across schools in the school district and state.
- Low socioeconomic status (SES) school: For the purposes of sampling in this study, a low SES school is defined as a school serving a population of students with 50% or more qualifying for the federal free or reduced school lunch program.

CHAPTER 2

REVIEW OF RESEARCH

In developing a theoretical framework that informs the underlying assumptions and decisions of this study, it is necessary to first explore the existing research into the science achievement gap phenomenon, its underlying causes related to poverty, current science reform practices, science inquiry instruction, culturally relevant pedagogies and practices, and the challenges faced by elementary teachers tasked with providing rigorous, inquiry-focused science instruction.

SEARCH PARAMETERS

Guided by the research questions, studies were selected based on a variety of criteria. Studies were selected that examined the issues related to the presences of the science achievement gap in schools serving students in low SES communities. In addition to poverty, studies were also selected that examined the science achievement gap as a function of ethnicity and language status. Some studies were selected because they described the presence of the science achievement gap at different grade levels and for different demographic groups. Some studies were selected because they examined efforts to close the science achievement gap through different professional development efforts. Finally, studies were selected that examined the impact of poverty on students, schools, and achievement in general terms.

Proceeding from the premise that science inquiry teaching has the potential to reduce the achievement gap through providing students with a share set of authentic science learning experiences, studies were also selected that examined the nature of constructivist science inquiry practices. Studies were selected based on the degree to which they defined the characteristics of science inquiry and authentic science practices as learning through knowledge-constructing experiences. Though influenced by the underlying assumptions presented in *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012), studies were not limited to only those that examined science and engineering practices congruent with the way they are defined in the NRC *Framework*. Furthermore, studies were also considered that examined effective science teaching to diverse student populations through the lens of culturally relevant pedagogy.

Finally, owing to the various systemic barriers to teaching effective, rigorous, inquiry-focused science in the elementary setting, studies were selected that investigated this phenomenon with regard to the underlying causes of these challenges as they relate to elementary teacher science content knowledge, experience with and understanding of science inquiry practices, and the degree to which elementary schools prioritize other subjects, such as ELA and mathematics, over science.

THEORETICAL FRAMEWORKS

As a result of the research reviewed for this study, two main theoretical frameworks emerged that underlie the primary assumptions and inform the design of this study. In seeking to identify and define instructional practices, pedagogical principles, and teacher beliefs that are evident in elementary teachers in schools with significant free

or reduced lunch populations whose students outperform their peers with regard to science achievement, it is necessary to first define what effective science instruction in the elementary setting looks like and to understand the systemic challenges faced by teachers in that setting.

Defining Science Inquiry Teaching.

Rigorous, inquiry-focused science instruction is best defined as a processes by which students engage in authentic practices of science with the goal of constructing knowledge through experiential learning (Kim & King, 2012; Passmore, Stewart, & Cartier, 2009; Wu & Hsieh, 2006). *A Framework for K-12 Science Education* outlines a vision for science and engineering education in which students engage in the practices of scientists and engineers in order to construct knowledge regarding natural phenomena, develop understanding of science concepts, and communicate their understanding and knowledge in a manner consistent with these authentic practices (NRC, 2012).

Additionally, the framework makes the case for learning science learning taking place through the integration of science concepts and genuine practices through the processes of scientific inquiry and engineering design (NRC, 2012). In essence, the framework document seeks to define science learning as a practice by which students develop a deep understanding of science concepts through the application of authentic science and engineering practices. This approach to science learning through the application of authentic practices that lead to students constructing explanations from data gathered during investigations is congruent with the broader defining characteristics of constructivist learning (Braaten & Windschitl, 2011; Cavagnetto, Hand, & Norton-Meier, 2010; Watters & Diezmann, 2007; Windschitl, 2002). In a constructivist

framework, students engage in the process of constructing conceptual knowledge through the applications of authentic science practices, social interactions, and new experiences that challenge prior knowledge and misconceptions of natural phenomena (Chiatula, 2015; Faircloth & Miller, 2011; Tippett, 2009; Vygotsky, 1978).

Barriers to Effective Science Teaching in Elementary Settings.

Teacher use of effective, rigorous, inquiry-focused science instruction in the elementary setting faces many systemic barriers owing to the very nature of elementary schools (Mensah, 2010; Sandholtz & Ringstaff, 2013). These challenges are related to the tendency for elementary schools to prioritize ELA and mathematics over science with regard to expectations of instructional time, support for materials and resources, and professional development (Johnson & Fargo, 2014; Mensah, 2010; Sherman & MacDonald, 2008; Slavin, Lake, Hanley, and Thurston, 2014). In addition to these systemic barriers to high quality science inquiry teaching, elementary teachers tend to be generalists with little experience in teaching science through constructivist, authentic inquiry practices (Akerson, et. al., 2009; Gutierrez, 2005; Ricketts, 2014; Watters & Diezmann, 2007). Elementary teachers also tend to lack an understanding of the science knowledge and concepts related to the content they teach (Diaconu, Radigan, Suskavcevic, & Nichol, 2012; Sandholtz & Ringstaff, 2013; Slavin, Lake, Hanley, & Thurston, 2014; Thomson & Kaufmann, 2013). Combined, these two factors result in elementary teachers in general lacking confidence, and feeling less qualified when it comes to teaching rigorous, accurate science content through authentic science inquiry practices (Deniz & Akerson, 2013; Mensah, 2010; Sandholtz & Ringstaff, 2013; Smith, 2014).

Defining Culturally Relevant Pedagogy.

In addition to defining science inquiry as a constructivist-informed approach to teaching science through authentic, knowledge-building experiences, it is necessary to define the methods of culturally relevant pedagogy a means of empowering diverse students to be successful in school. Culturally relevant pedagogy recognizes that the existing culture within a school, defined by rules, both overt and covert, values, norms, priorities, and power structures, can often be a barrier to students who hold a different set of culturally defined norms, values, and priorities (Ladson-Billings, 1995; Laughter & Adams, 2012; Lee, 2004; Phelan, Davidson, & Cao, 1991). Teachers who understand this tension can take steps to help students overcome the barriers erected by this cultural incongruence and empower students to connect with their learning and be successful navigating the culture of school in general and science in particular through grounding the learning in contexts and priorities that are familiar, meaningful, and personally relevant to the students, as well as communicating high expectations regarding the ability for all students to be successful in school (Ladson-Billings, 1995; Laughter & Adams, 2012; Lee, 2004; Phelan, Davidson, & Cao, 1991). It is also important to note that, in addition to the use of authentic, meaningful context, culturally relevant pedagogies and practices are congruent with a constructivist approach to science teaching in the view that knowledge not as a rigid thing to be memorized but as a fluid state that is constructed through shared experiences and interactions and that it must be viewed critically by both the learner and the teacher (Ladson-Billings, 1995; NRC, 2012).

Nature of the Science Achievement Gap vis-à-vis Poverty.

Finally, in seeking to identify practices, pedagogies, and beliefs that demonstrate effectiveness at helping students in poverty overcome the science achievement gap, it is necessary to define the nature of this achievement gap. When comparing measurements of science achievement between different groups of students, a pattern emerges whereby students from a more privileged background typically outperform their less privileged counterparts, regardless of whether that distinction is based on ethnicity, language status, or poverty (Curran & Kellogg, 2016; Noble, Rosebery, Suarze, Warren, & O'Connor, 2014; Quinn & Cooc, 2015; Vijil, Slate, & Combs; 2012). Studies into the nature of the achievement gap across different demographics breaks the root causes into two main areas. One area of study focuses on the impact of poverty on the individual, their family, and their community. Poverty can impact the ability of a family to access quality health care, provide for reliable, stimulating daycare, and provide cognitively stimulating enrichments, all of which can impact chances for student success in school (Berliner, 2006; Crook & Evans, 2014; Garcy, 2009; Ladd, 2012). Additionally, children growing up in poverty are less likely to have access to a wide variety of resources or life experiences when compared with students from middle to high SES families, such as robust home libraries, computers and online access, or travel away from their home communities, factors that more privileged children are able to leverage to their advantage in the traditional school dynamic (Dearing et. al., 2016; Ladd, 2012; Sirin, 2005).

Studies into the nature of the achievement gap have also examined the impact of poverty on schools serving low SES communities. Schools serving low SES communities are more likely to struggle recruiting and retaining quality, experienced teachers who are

certified to teach in critical needs areas such as science and math (Balfanz & Byrnes, 2006; Geier, et. al., 2008; Hani, 2012; Ladd, 2012). Additionally, such schools also tend to lack the materials and up to date resources necessary to successfully engage their diverse student populations in rigorous learning experiences as a results of the economic segregation that occurs through the uneven funding of schools from different socioeconomic neighborhoods (Chudgar & Luschei, 2009; Duke, 2000; Ladd, 2012; Pribesh, Gavigan, & Dickinson, 2011).

As a result of these two sets of variables that define the way poverty can impact student achievement, it is necessary to consider the solutions to the problem of the science achievement gap from two perspectives. One way of examining efforts to overcome the achievement gap is to look at how a teacher can provide equitable, authentic learning upon which every student can construct science knowledge through authentic, contextualized experiences that allow for the development of conceptual understanding. By providing shared science learning experiences that allow students the opportunity to collect and analyze data through authentic science investigations and research, the learner is guided through the process of constructing a conceptual understanding based on their own data and experiences as opposed to building conceptual knowledge almost exclusively upon prior knowledge or the capacity to learn science from a more traditional, didactic approach. When these data-driven, student-constructed, conceptual understandings lead to the development of representational scientific models that illustrate how the learned has come to understand key science concepts, then the representation of student learning is not merely the capacity to reiterate memorized science facts that may or may not illustrate a deeper conceptual understanding but rather

student understanding can be measured through their own representational construct. Furthermore, it is equally important to understanding the ways a teacher can create a climate of learning in the classroom that does not automatically disadvantage diverse students but rather honors and leverages the their cultural identities and communicates high expectations of success for all learners.

Therefore it is likely that teachers in the low SES schools whose students are successful at closing the achievement gap in science share a certain set of characteristics common to both authentic constructivist science inquiry practices and culturally relevant pedagogies, though not necessarily in even proportions. Through a constructivist approach to science teaching, a teacher would engage all of her students through an authentic experience, such as an investigation, problem, or design challenge that serves to illustrate some natural phenomenon. Through this experience, students would gather and analyze data in an effort to construct an explanation for the phenomenon or develop a solution to the problem. In this way, the shared authentic experience becomes the foundation from which the students gather evidence and upon which they eventually construct their knowledge. In doing so, students do not need to rely as heavily on prior knowledge or experiences acquired outside of the classroom or knowledge acquisition skills that rely heavily upon note taking, reading complex, often uninteresting, texts, and the memorization of abstract concepts and discrete facts (Adesoji & Idika, 2015; Cuevas, Lee, Hart, & Deaktor, 2005; Yang, Lin, She, & Huang, 2015).

In addition to these constructivist traits, there would likely also be evidence of culturally relevant instructional practices in this teacher's classroom. In order to connect with her diverse student population, the teacher would overtly communicate high

expectations that all of her students are capable of succeeding in learning science. Congruent with constructivist pedagogy, she would overtly contextualize the learning through ideas, settings, problems, and scenarios not only familiar to her students but also personally relevant and important to them. In this way, the students would not feel isolated from the learning climate in her classroom; rather they would readily identify with not only what they are learning but also why it is important to learn and how they might use that information to take action to improve their own community. Through these explicit efforts, these students would feel welcomed in the classroom and empowered and confident in their abilities as scientists to be successful in school. Taken together, both of these would help her students to accomplish her learning goals and, assuming congruency between the classroom goals and the performance expectations of the state's science standards, meet or exceed the expectations as measured on the end of the year state science assessment.

REVIEW OF RESEARCH

Science Inquiry Practices as Social Constructivist Learning.

In order to examine science learning as a constructivist endeavor, it is first necessary to understand the defining characteristics of constructivism as it pertains to learning in general. As stated earlier, constructivism describes learning through which knowledge is built through social interactions as new experiences challenge older knowledge (Bryant & Bates, 2015; Chiatula, 2015; Tippett, 2009; Vygotsky, 1978). Rather than see herself as an authority or source of knowledge to be conveyed, the constructivist teacher sees her role as creating a social context in which learning can occur. The teacher gives direction and communicates expectations, norms, and protocols

that inform how the students will work collaboratively and socially to construct learning (Brophy, 2010). In this social setting, learning occurs when old ideas and knowledge are confronted and challenged by new ideas and knowledge (Doolittle, 2014; Tippett, 2009). As opposed to a behaviorist approach to learning in which knowledge is seen as fixed and rigid and where facts are to be memorized and accepted at face value (Deubel, 2003; Skinner, 1989), in the constructivist setting, learning occurs in an authentic context that mirrors real-world scenarios (Bryant & Bates, 2015). This authenticity helps provide legitimacy to the learning by demonstrating why it is necessary to challenge established understandings with new ones (Brooks & Brooks, 1999; Chiatula, 2015; Faircloth & Miller, 2011). In addition to authenticity, the constructivist teacher strives to make the learning personally relevant. Not only is the learner provided with a sense of legitimacy for acquiring and assimilating new knowledge, the reasons for learning are seen to directly impact his or her life. When something is seen as personally relevant, a learner is going to place more value on the experience. This, in turn, not only produces more sustained engagement, but supports management of the learning environment (Brooks & Brooks, 1999; Faircloth & Miller, 2011; Oldfather, 1993).

This vision of science education and learning through the application of knowledge-building practices is in alignment with these elements of constructivist learning. Braaten and Windschitl (2011) describe reform efforts in science education as science learning through the construction of scientific knowledge and conceptual understanding that focuses on key ideas and practices. The connection between scientific inquiry and constructivism is more evident when science learning is viewed not as a body of knowledge but as a process by which knowledge is constructed through situated,

experiential learning whereby the outcomes of the learning experience, along with the interactions that occur during the learning, allow for new knowledge to be developed or refined by the students (Braaten & Windschitl, 2011; Watters & Diezmann, 2007; Windschitl, 2002). Cavagnetto, Hand, and Norton-Meier (2010) connect learning through scientific inquiry with the constructivist theory of learning in which new experiences are integrated into the learner's prior knowledge.

In addition to the congruent nature of both science inquiry and constructivism where it pertains to the process of knowledge construction, there is also alignment in the dual visions of learn as an inherently social endeavor. Constructivism recognizes that learning is situated in context and that knowledge evolves through experience and interaction, not with the phenomenon under investigation but also with fellow learners (Bryant & Bates, 2015; Chiatula, 2015; Tippett, 2009; Vygotsky, 1978). Similarly, the NRC *Framework* (2012) describes how science is “fundamentally a social enterprise, and scientific knowledge advances through collaboration and in the context of a social system with well-developed norms” (p. 27). The authors go on to explain how collaboration and interaction are at the heart of the scientific endeavor.

Individual scientists may do much of their work independently or they may collaborate closely with colleagues. Thus, new ideas can be the product of one mind or many working together. However, the theories, models, instruments, and methods for collecting and displaying data, as well as the norms for building arguments from evidence, are developed collectively in a vast network of scientists working together over extended periods. As they carry out their research, scientists talk frequently with their colleagues, both formally and informally... In short,

scientists constitute a community whose members work together to build a body of evidence and devise and test theories (NRC, 2012, p. 27).

Characteristics of Culturally Relevant Pedagogy.

Culturally relevant pedagogy shares several key elements with a constructivist approach to teaching science through authentic, inquiry-focused practices. Culturally relevant teaching requires the teacher take into account the cultural identities and perspectives of his or her students and how they shape the way a student engages in the learning experience as well as what the student prioritizes (Gao & Wang, 2016; Grimberg & Gummer, 2013). In her studies of successful teachers of African-American students, Ladson-Billings (1995) found that they shared four traits: the belief that their students were capable of being academically successful, the idea that their pedagogy was akin to an art as opposed to a rigid set of actions or tasks, the view that they were a part of a shared community with their students along with the idea that their teaching was a way of giving back to this community, and that their task as teachers was one of pulling knowledge out of their students as opposed to pushing information in.

Grimberg and Gummer (2013) explain that the successful execution of culturally relevant instruction “approaches content knowledge in such a way that it affirms students’ values and competences related to a particular cultural group (students’ cultural competence) and enhances their communities (students’ critical social consciousness) would result in students’ achievement gains (students’ academic success)” (p. 13-14). Successful integration of culture with science instruction occurs when teachers understand and value the cultures of their students, understand the nature of science, and

connect learning to the experiences and values of their students (Grimberg & Gummer, 2013; Lee, 2004).

Grimberg and Gummer (2013) studied the impact of professional development to support the creation of culturally relevant science instructional units in a Native American community in Montana. Their study found that when efforts were made to connect core science concepts, such as forces and motion, with arrow making and throwing, student achievement increased as students saw connections between the science topics they were learning, the hands-on activities they were engaging in and their own cultural identities and issues personally relevant to them. These efforts included presentations of these culturally relevant topics by members of the community, in this case, tribal elders. Additionally, as a result of the professional development efforts, teachers reported increased confidence in their ability to teach science content as well as enact equitable teaching strategies (Grimberg & Gummer, 2013). In a study of English Language Learner (ELL) populations in a culturally diverse elementary school, Lee (2004) described an example of instructional congruence whereby a science unit about weather included terms in Spanish and made references to locations and climate familiar to the Hispanic students in the classes in a way that allowed them to connect with the examples described in the learning. In another example, a middle school science teacher who included topics of social justice related to science in her lesson found that her students outperformed expectations, despite the cautioning of his colleagues that such topics would only create an atmosphere in the class of racial tension and would result numerous inappropriate, racial comments (Laughter & Adams, 2012). The teacher

attributed her success, in part, to her own belief that her students were capable of more than her peers believed (Laughter & Adams, 2012).

Central to these examples is the notion that culturally relevant instruction takes into account the cultural identities of the students in the teacher's class as well as what their culture prioritizes. Explicit efforts to connect science content and concepts with ideas, activities, and events that are important to the unique cultural identity of the students are essential to implementing successful culturally relevant instruction that results in student achievement. At the same time, it is important that the teacher holds a view of the students as capable learners whose cultural identities are a source of strength to the learning and not an impediment.

A culturally relevant framework views the learning environment as a process of navigating different cultures. In many ways, the nature of science is, itself, a form of culture, one in which there is a set of norms, structures, practices, rules, values, and expected outcomes that produce knowledge which, in turn, continues to shape the nature of the culture itself (Laughter & Adams, 2012; NRC, 2012). The institute of education is also its own culture, with its own overt and covert rules defining the norms, values, power structures, interactions, and expected outcomes (Grimberg & Gummer, 2013; Lee, 2004). Taken together, science education can be considered another culture that blends elements of both the nature of science and educational institutions. As with any culture, there are those who approach these cultures as insiders already familiar with these rules and norms and there are those who are outsiders, whose own cultural identities may be at odds with these structures. For the insider, there is an advantage born from this familiarity, one that allows for easy navigation and acclimation into the culture of school

and science. For the outsiders, the different perspective can make it all the more challenging to understand and be successful in what might be viewed as an alien world. If the cultures of education and science are rigid, the burden falls to the student to successfully navigate the complex set of rules, norms, and structures in order to function successfully. If the student's own culture is not immediately compatible with these cultures, the outsider will find it increasingly difficult to be successful in a setting and process that conflicts with his or her own values, power structures, rules, norms, and expected outcomes. This lack of cultural congruence can, in turn, create tensions between cultural power structures, in particular between teacher and student (Ladson-Billings, 1995; Phelan, Davidson, & Cao, 1991). This is especially the case if the culture of science education in the classroom follows a more traditional, didactic, behaviorist philosophy as opposed to a more constructivist, inquiry-driven approach.

In comparing culturally relevant pedagogy with constructivist science inquiry practices, three common elements become apparent. Ladson-Billings (1995), in her studies of effective teachers of African-American students, found that they viewed knowledge not as a rigid thing to be memorized but as a fluid state that is constructed through shared experiences and interactions and that it must be viewed critically by both the learner and the teacher. In this way, these teachers held an understanding of knowledge very much in alignment with the same constructivist views that underlie the development of scientific knowledge in the inquiry classroom. Additionally, both culturally relevant pedagogy and constructivism recognize the importance of contextualizing the learning in a way that is familiar, important, and personally relevant

to the learner (Faircloth & Miller, 2011; Grimberg & Gummer, 2013; Lee, 2004; Oldfather, 1993).

Finally, in promoting the idea of science education for all, the NRC *Framework* (2012) describes how in science education there “is increasing recognition that the diverse customs and orientations that members of different cultural communities bring both to formal and to informal science learning contexts are assets on which to build—both for the benefit of the student and ultimately of science itself” (p. 28), a notion congruent with the ideas of culturally relevant pedagogy.

Wlodkowski and Ginsberg (1995) lay out a four-part framework that synthesizes the elements of CRP into a coherent model for establishing a culturally relevant environment in the classroom. First among these elements is establishing inclusion through establishing relatable purpose for the learning, sharing ownership for the learning, fostering collaboration and cooperation, and treating students equitably. The second element is developing a positive attitude towards the learning by connecting the learning to prior knowledge and experience as well as by fostering choice with regard to activities and assessments. The third part of this framework involves engaging students in rigorous, higher-order thinking and inquiry through connections to authentic problems and scenarios as well as encouraging discussion and student voice. The final element of this framework is to engender competence through varied and authentic forms of assessment, including self-assessment. This framework has the potential foster an intrinsic motivation that will help students connect with and see the value of the learning in a way that makes it relevant to their cultural and personal identities, overcoming the

disconnect that can occur when the learner views himself or herself as an outsider to the classroom culture (Ladson-Billings, 1995; Phelan, Davidson, & Cao, 1991).

These framework elements are similar to those employed in the design of Culturally Responsive Instruction Observation Protocol (CRIOP), developed to assess CRP teaching practices (Powell, Cantrell, Malo-Juvera, & Correll, 2016). The domains of the CRIOP include the following: classroom relationships (care, respect, and high expectations), family collaboration (equitable partnership and leverage of family resources), formative assessment (inclusive in nature and used to gauge student understanding and modify instruction), culturally planned learning experiences (depict diverse experiences and are relevant), pedagogy/instruction activities (active, meaningful, engaging, elements of choice), discourse (interactive, engaging, student voice, content specific), and sociopolitical consciousness (social justice, community-related).

In a study of high school teachers who had been trained on CRP, these teachers showed a shift in their practices towards elements congruent with a CRP framework, including making relevant connections between the students and the content, situating the students as knowledge authorities in the classroom, community building through interaction and giving students voice, and making connections between school and students' homes (Brown & Crippen, 2016).

When teachers engage in CRP, they create a positive classroom environment where students see the value of their efforts in a context that is relevant and familiar to their lives. They see that their teacher values them as individuals and believes in their ability to be successful in achieving high standards of performance. The impact of such a positive classroom environment is that students are more likely to be engaged when there

is a positive relationship between them and their teacher. This positive relationship can also foster not only engagement but also achievement (Kipkoech, Kindiki, & Tarus, 2011; Roorda, Jak, Zee, Oort, & Koomen, 2017).

Barriers to Effective Science Teaching in the Elementary Setting.

In the elementary school setting, teachers and providers of professional development are faced with specific challenges when it comes to implementing authentic scientific inquiry through the application of science and engineering practices.

Elementary teachers are less likely to have experienced genuine scientific inquiry in their own education background or teacher preparation programs. This makes it likely that they will not emphasize consistent scientific inquiry practices in their own work with students (Akerson, et. al., 2009; Ricketts, 2014; Schwarz & Gwekwerere, 2007; Watters & Diezmann, 2007). Akerson, et. al. (2009) found that it was difficult providing professional learning to elementary teachers in the area of science inquiry teaching methods because most had limited if any experiences with this manner of teaching science. Sherman and MacDonald (2008) noted that the lack of hands-on science experience with elementary teachers was one of the main challenges in attempting to enact science reform efforts. Owing to this lack of experience with scientific inquiry, elementary teachers tend to view science as a rigid body of knowledge to be learned through textbooks, direction instruction, and similar passive instructional methods rather than through a process of inquiry and discovery (Diaconu, Radigan, Suskavcevic, & Nichol, 2012).

Compounding the lack of experience with inquiry instruction, there is also a lack of clarity in defining the characteristics of scientific inquiry which leads to discrepancies

and inconsistent implementation of authentic science inquiry practices, in particular explanation construction and argumentation, in not only the elementary settings, but across all levels of K-12 education (Bricker & Bell, 2008; McNeill & Krajcik, 2007; Passmore, Stewart, & Cartier, 2009; Windschitl, 2002). Osborn and Patterson (2011) noted how these discrepancies can result in confusion with the practices of argumentation and explanation construction. As a result, if teachers are to enact reform-based science that calls upon the use of authentic science practices as the means by which students construct knowledge, teacher will need to be provide with the kind of professional learning that allows them to unpack the characteristics and goals of these practice in order to understand and implement them with their students (Berland and Reiser, 2008). Additionally, Berland and Reiser (2008) found that the practice of constructing and defending explanations did not typically occur in the classroom unless the practice was taught in isolation or as the primary focus of instruction. This is a further compounded when there is little consensus within the science education community about the exact nature of explanation construction in the first place, often leading to a focus on acquiring and repeating descriptive information without developing a genuine explanation for why a scientific phenomenon occurs (Braaten & Windschitl, 2011). As a result, science inquiry instruction has become complicated by an environment of inconsistency with regard to the exact nature of these practices as well as the manner in which they should be implemented in the classroom, including discrepancies in the relationship between science content and process as well as the distinction between science inquiry and inquiry methods of teaching science (Haefner & Zembal-Saul, 2004).

This lack of experience with scientific inquiry can lead a great deal of confusion with what exactly is meant by inquiry teaching and learning, as well as how best to implement it (Bricker & Bell, 2008; McNeill & Krajcik, 2007; Passmore, Stewart, & Cartier, 2009; Windschitl, 2002). Because of this lack of a clear definition of the nature of science inquiry teaching practices, there is a great deal of confusion among the educators who on how to implement this type of instruction (Smith, 2014). Akerson, et. al. (2009) find that teachers tend to view teaching through inquiry as difficult because of a general sense of confusion about the meaning of inquiry, as well as inadequate preparation with inquiry methodologies. Gutierrez (2015) notes that misconceptions about the difficult and time-consuming nature of science inquiry teaching and learning result teachers experiencing in uncertainty and hesitancy in how to implement inquiry in their classes.

As a result of this confusion, stemming from a lack of clarity, understanding, and experience with inquiry, there is a persistent lack of effort in the use of scientific inquiry practices such as explanation construction, argumentation, and modeling in elementary science classrooms (Kim & Hand, 2015; Lin, 2014; McNeill, 2011; Zangori & Forbes, 2013; Zangori & Forbes, 2014). This lack of understanding often results in a simplistic approach to the use of scientific inquiry, where inquiry is seen as little more than a series of activities and scientific practices are used to engage students in the act of doing hands-on science without engaging in the act of knowledge building (Haefner & Zembal-Saul, 2004; Kim & King, 2012; Nelson & Davis, 2012; Varelas, et. al., 2007). Also, the practices of inquiry, explanation construction, argumentation, and modeling are often not explicitly taught as part of elementary science instruction, resulting in an inability on the

part of the students to successfully engage in genuine knowledge building experiences (Berland & Reiser, 2008; Lin, 2014; Nelson & Davis, 2012; Zangori, Forbes, & Biggers, 2013). Finally, elementary teachers often find it difficult to help students in the use of evidence and reasoning to construct explanations, engage in argumentation, and develop explanatory and scientific models. Essentially, elementary teachers face many challenges when engaging students through authentic inquiry practices to foster scientific knowledge building (Braaten & Windschitl, 2011; Lehrer & Schauble, 2012; McNeill & Krajcik, 2007; Wu & Hsieh, 2006). Given the connection between constructivism and science inquiry practices, this lack of understanding, experience, and confidence is unsettling as it constitutes a genuine threat to the efforts to create equitable learning environments for all students through the implementation of knowledge-building constructivist science inquiry practices.

Further complicating the effective use of authentic science inquiry practices in the elementary setting is the tendency for elementary teachers to be generalists with little exposure to science courses that would have helped them to develop a robust foundation of science content knowledge or an in depth understanding of underlying science concepts and principles (Deniz & Akerson, 2013; Sandholtz & Ringstaff, 2013; Slavin, Lake, Hanley, & Thurston, 2014; Thomson & Kaufmann, 2013). Prospective elementary educators often enter their pre-service training with little confidence in their ability to teach science, feeling the lack the background to teach science at even the lower elementary level. (Sherman & MacDonald, 2008). Slavin, Lake, Hanley, and Thurston (2014) cite that as a result, elementary science is typically taught by non-science

generalist who are responsible for teaching multiple content areas and who rarely have a university degree in a science field.

This lack of a strong science content background means that most elementary teacher are not science experts in that they do not have a strong science content knowledge background, an understanding of the nature of science inquiry instruction, and are generally not comfortable teaching science (Mensah, 2010). This, in turn, impacts the confidence of elementary teachers when it comes to teaching science. Few elementary teachers reporting feeling strong in teaching science when compared to their sense of efficacy teaching other content areas, such as ELA or mathematics (Sandholtz & Ringstaff, 2013). In general, elementary teachers lack the confidence to feel competent teaching science as a result of a lack of science content and pedagogical content knowledge. (Deniz & Akerson, 2013; Smith, 2014).

Finally, the nature of the elementary setting itself produces systemic barriers to effective science inquiry teaching (Mensah, 2010; Sandholtz & Ringstaff, 2013). Mensah (2010) finds that “the ideals and goals of what science teaching should look like in elementary schools become false allusions in the midst of oppressive policies and traditional schooling discourses” (p. 981). This, Mensah (2010) notes, results in science teaching and learning often being marginalized in the elementary setting in favor of prioritizing other content areas.

A frequently cited impediment to authentic inquiry-driven science teaching and learning is that teachers feel they do not have enough time or are not allowed to dedicate a sufficient amount of time to teaching science because of the imposition of a greater focus on mathematics and literacy (Sherman & MacDonald, 2008). This often results in

science not only receiving the amount of time needed to teach it effectively, but also not receiving the necessary resources, as time and resources get allocated to reading and math (Slavin, Lake, Hanley, and Thurston, 2014). Additionally, lack of familiarity with science content, coupled with the breadth of state science standards can undermine effective science teaching and learning. Together, the lack of familiarity with science content and inquiry, the prioritization of other subjects over science, and the sheer breadth of science content required by many state science standards results in teachers resorting to more traditional, didactic methods of teaching science even when they see the benefit and have a design for teaching science through hands-on, science inquiry practices (Gutierrez, 2015). The impact of this reduction in dedicated time for science instruction can be seen in student outcomes, with reduced science teaching resulting in lower science achievement (Blank, 2013).

High-stakes testing is often cited as a reason for this reduced emphasis on hands-on science (Johnson & Fargo, 2014). Gutierrez (2015) finds that existing structures in elementary schools often serve as an impediment to teaching inquiry-based science in place where the prioritization of standardized accountability measures often results in teachers feeling that they only have time to directly teach to the facts that are known to be measured on the system-wide assessments. This focus on standardized testing, which more frequently occurs in math and language arts, often results in school-level regulations and administrative decisions that get in the way of teachers' attempts to teach science, resulting in teachers either rarely teaching science, often as seldom as once a week, or integrating science into other content areas in such a way that science becomes something that is read about and not actively practiced (Thomson & Kaufmann, 2013).

The systemic lack of focus on authentic, inquiry-driven science teaching and learning also has a negative impact on elementary science professional learning. Science professional development is also marginalized in the elementary setting as a result of the limited days a teacher can be away from class, difficulty finding substitute coverage, and an emphasis of on high-stakes assessment preparation in other content areas, primarily ELA and math (Adamson, Santau and Lee, 2012; Thomson & Kaufmann, 2013). When schools and school systems undermine science teaching and learning, it becomes “unclear if professional development programs can support science teachers to produce growth in student outcomes for any ethnic or racial group in this climate of high-stakes accountability where science is often shortchanged in instructional time if included at all, and when taught is delivered in a very teacher-centered manner” (Johnson & Fargo, 2014, p. 846). In one case, it is described that participants in a yearlong science professional development program failed to complete it fully as a result of these systemic external pressures (Thomson & Kaufmann, 2013).

Another negative outcome that can be considered a reflection of the systemic challenges facing effective science teaching and learning in the elementary setting is the impact these challenges have on traditionally underserved populations. In calling for science teaching reform, The *Framework* (2012) notes that in order to provide equitable access to both the science and engineering practices and the science content knowledge associated with science and engineering careers, it is essential that students have more equitable achievement in science and engineering literacy and skills. However, the challenges associated with teaching reform-based science in the elementary settings are exacerbated when it comes to reaching traditionally underserved populations in the

education system. (Adamson, Santau, & Lee, 2012). The struggles with reaching underserved populations can stem from the limited experiences elementary teachers typically have with science content and inquiry. Diaconu, Radigan, Suskavcevic, and Nichol (2012) cite that when the lack of science content knowledge and experience with science inquiry practices is coupled with the low knowledge based and skill level often associated students coming from high poverty urban areas make it challenging for teachers to employ reform-based science teaching methods. Subsequently, “if urban teachers do implement inquiry-based instruction, they are likely to do a demonstration for the class while asking fact-based questions prefaced by ‘what’ and ‘how’ rather than asking probing questions that help students build conceptual understanding” (Diaconu, Radigan, Suskavcevic, & Nichol, 2012, p.856). In addition to the impact on urban school populations, science is often considered a cultural-neutral discipline, resulting in its teaching without recognizing the cultural, language, or personal relevance of the students’ backgrounds, particularly Hispanic students (Johnson & Fargo, 2014). When combined with the impact of the systemic challenges already faced by elementary teachers struggling to find time to teach science, with low SES schools, this can result in even lower student outcomes resulting from the reduced instructional focus on science (Blank, 2013).

This information helps to frame part of the challenges that define the problem faced by elementary schools in addressing the science achievement gap for students living poverty. It is also important to consider these challenges, especially in light of the theoretical framework that it is possible through the use of constructivist science inquiry practices that students in poverty might be able to overcome the persistent achievement

gap. Given the additional challenge faced by schools serving low SES communities of recruiting and retaining highly qualified teachers, it makes it all the more unlikely that students in these schools will have the opportunity to benefit from these instructional practices.

Science Achievement Gap.

The achievement gap in science is well documented in recent literature, though much of the research examines this gap through the lens of ethnicity as opposed to indices of poverty. In Massachusetts, 36 grade 5 students were given publicly released multiple choice items from the state's standardized test aligned to specific life science and physical science standards. The sample of students consisted of 12 ELL students and 24 non-ELL students. Additionally, these students were interviewed to determine their level of understanding of the science concepts aligned with the assessment items. In this study, ELL students were more likely to demonstrate an accurate understanding of the science concepts through their interview responses even as they were more likely to score incorrect on the assessment items (Noble, Rosebery, Suarze, Warren, & O'Connor, 2014). Through interviews with the students, it was determined that the ELL students who score incorrectly on the assessment items even though they showed an accurate understanding of the underlying science concepts did so because of a lack of understanding of the language used in the assessment item. As a result of an inaccurate and alternate interpretation of the language presented in the questions they were asked, ELL students would often answer different scientific questions than the ones that were intended.

In study that examined the achievement gap between White and Hispanic students, Vijil, Slate, and Combs (2012) studied the results of students who took the Texas Assessment of Knowledge and Skills (TAKS) in grades 5, 8, and 11 over a three year period from 2006 through 2008. Over the three year period, the percentage of grade 5 White students who passed the TAKS ranged from 83.90 to 87.67 while grade 5 Hispanic students passed at a lower rate, from 67.65 to 75.78 percent. For grade 8, White students passed at rates of 78.72 to 83.66 percent compared with 58.74 to 63.72 percent for Hispanic students. Results were similar in grade 11, ranging from 82.82 to 86.97 percent for White students and 62.97 to 70.29 percent for Hispanic students (Vijil, Slate, & Combs, 2012).

Even at Kindergarten and grade 1, there is evidence of this persistent science achievement gap between both African-American and White students and between Hispanic and White students (Curran & Kellogg, 2016). Using data from the Early Childhood Longitudinal Study (ECLS-K: 2011), a nationally represented set of students from the Kindergarten class of 2010-2011 whose progress is tracked through fifth grade, the researchers were able to compare science achievement results between White and Hispanic students and White and African-American student in grades Kindergarten and 1st. The comparison indicated that as early as Kindergarten, there is already an ethnicity-based science achievement gap, with a standardized achievement gap in Kindergarten of -0.9 for Hispanic students and -0.8 for African-American students. By grade 1, the gap for Hispanic students begins to narrow to -0.7 while remaining constant for African-American students (Curran & Kellogg, 2016). In a similar study of early ECLS-K:99 data, researchers noticed that although the achievement gap narrows between grades 3

and 8 for Hispanic students and African-American students compared with White students, it still persisted throughout elementary and middle school (Quinn & Cooc, 2015).

Santau, Maerten-Rivera, and Huggins (2011) examined the results of a 5-year professional development effort designed to improve science and literacy achievement among ELL students. The professional development intervention consisted of curriculum units and teacher workshops designed to support teachers in teaching inquiry-based science as well as support ELL students. During a three year period of the intervention, students in grade 4 were assessed using items from the National Assessment of Educational Progress (NAEP) and Trends in Mathematics and Science Study (TIMSS) assessments. Students whose teachers benefited from the professional development intervention showed steady gains in science achievement. Additionally, there was no significant achievement gap between English as a Second of Other Language (ESOL) students and students who had either exited ESOL support or who had never been classified as ESOL. When these students were compared with national and international norm groups, although they underperformed in comparison on the pre-test, they scored higher on the post-test (Santau, Maerten-Rivera, & Huggins; 2011).

The Impact of Poverty on Student Learning.

Numerous studies have examined a myriad of issues related to how poverty impacts school achievement, whether specifically at the achievement gap as measured on standardized tests or in a more general way at how the different elements associated with poverty impact student learning and engagement with schools. In general, these issues can be broken into two broad categories: factors that are directly related how poverty

impacts decisions or actions of the teacher, school, or district and factors that are largely related to how a student is affected by the impact of poverty on his or her family or larger community beyond the school walls. Taken together, these various factors have the capacity to both directly and indirectly impact a student's chances of achieving success in school.

Schools located in low SES neighborhoods are more likely to experience reduced funding compared with schools in other communities (Lee, 2012; Sirin, 2005). This limited funding can impact the achievement of the students in these schools in a myriad of ways and create a form of economic segregation, whereby families in low SES communities are effectively forced to send their children to underfunded schools by comparison to schools in less impoverished communities (Gorard, 2016; Sirin, 2005). This lack of funding can result in these schools having out of date facilities that are badly in need to maintenance, and upgrading (Hani, 2012; Whipple, Evans, Barry, & Maxwell, 2010).

Two of the most frequently cited challenges faced by schools serving low SES communities are how poverty affects the quality and experience of teachers as well as the quantity and quality of resources and materials teachers are expected to use when teaching their students. Numerous studies illustrate that student achievement in all subjects is negatively impacted by the inability of schools serving low SES neighborhoods to recruit and retain highly qualified or experienced teachers. (Balfanz & Byrnes, 2006; Chudgar & Luschei, 2009; Clotfelter, Ladd, & Vigdor, 2010; Geier, et. al., 2008; Gorard, 2016; Hani, 2012; Johnson, Kahle, & Fargo, 2007; Ladd, 2012; Lee, 2012; Morgan, Farkas, Hillemeirer, & Maczuga, 2016; Quinn & Cooc, 2015; Whipple, Evans,

Barry, & Maxwell, 2010). In particular, when it comes to hard to teach subjects, such as mathematics, low SES schools typical struggle to hire highly qualified teachers who are certified to teach these challenging subjects (Balfanz & Byrnes, 2006; Lee, 2012). In addition to struggling to hire qualified, appropriately certified teachers, schools serving low SES communities have a harder time retaining those teachers, as many of these teachers who are successful in such a setting take advantage of the opportunity to transfer to a school in a higher SES neighborhood (Hani, 2012; Johnson, Kahle, & Fargo, 2007; Whipple, Evans, Barry, & Maxwell, 2010).

Furthermore, having a qualified teacher consistently in the classroom can also be impacted by the rate of absenteeism among teachers, with low SES schools having higher rates of absent teachers (Whipple, Evans, Barry, & Maxwell, 2010). The impact of hiring and retaining adequate, highly qualified staff extends beyond quality ELA and math teachers. Lapan, Gysbers, Stanley, and Pierce (2012) found that in Missouri, where the state made a significant effort to staff greater numbers of school counselors, this change resulted in a drop in discipline related issues as well as higher graduation rates. In contrast, schools in other states that were unable to support these staffing needs did not perform as well. In addition to the direct impact an unqualified or inexperienced teacher can have on the success of his or her students, the inability to hire and retain highly qualified, experienced teachers can also lead to increased class sizes (Chudgar & Luschei 2009; Hani, 2012).

One way the presence, or lack thereof, of a quality teacher can impact student achievement is in the way of expectations. Studies have found that in schools serving low SES communities, teachers are less likely to believe their students are capable of

achieving success in rigorous topics such as science as well as less likely to communicate high expectations to their students (Barnard-Brak, McGaha-Garnett, & Burley, 2011; Bottoms & Carpenter, 2003; Buxton, 2005; Petty, Chuang, & Harbaugh, 2013). Research into the impact of culturally relevant pedagogy illustrates that a teacher can have a positive impact on student achievement through the communication of high expectations and the notion that every student in the classroom is capable of achieving success (Buxton, 2005; Jeanpierre, 2007; Ladson-Billings, 1995; Laughler & Adams, 2012)

Another significant effect of poverty on student achievement is the lack of quality resources and instructional materials in schools serving low SES communities. Schools in these neighborhoods are more likely to lack the resources or materials they need to teach their subjects and those materials they do have are more likely to be out of date (Chudgar & Luschei, 2009; Duke, 2000; Hani, 2012; Ladd, 2012). For mathematics, in particular, the lack of up to date, rigorous curriculum materials and resources has been shown to negatively impact student achievement (Balfanz & Byrnes; 2006, Lee, 2012). With regard to ELA, Duke (2000) found that in the first grade classroom of low SES schools, students had diminished access to print materials in their environment and that the quality of those materials was lacking when compared with other schools. Pribesh, Gavigan, and Dickinson (2011) found that the lack of resources in low SES schools extended beyond the classroom and into the school libraries, where there were fewer books, smaller staff sizes, and reduced availability, both in terms of service and times when compared with schools in high SES communities. This, despite fact that students in these struggling schools were more likely to access library materials and resources than their counterparts in more affluent schools (Pribesh, Gavigan, & Dickinson, 2011).

The lack of quality resources and materials extends beyond curriculum resources and physical materials. Schools serving low SES communities are less likely to provide different opportunities that are present in other schools, such as access to rigorous learning experiences, project-based learning environment, advancement placement offerings, and higher level mathematics courses (Balfanz & Byrnes 2006; Barnard-Brak, McGaha-Garnett, & Burley, 2011; Duke 2000; Fisher, Frey, & Lapp, 2011). Furthermore, these struggling schools are less likely to provide additional ways for students to be supported or engaged beyond the routine classroom experiences, including tutoring, mentoring, and in school support mechanisms, as well as after school programs and athletics (Ladd, 2012; Shields, Walsh, & Lee-St. John, 2016).

The impact of poverty on a student's achievement extends beyond the ability of a school to provide access to quality materials and resources or exposure to highly qualified, experienced teachers. Many of the ways that poverty impacts a student's ability to successfully engage in school are beyond the control of, though not necessary beyond the influence of, the school entirely. These factors include ways that poverty impacts health and quality of life for the students, as well as the variety and quantity of opportunities and experiences a child may be exposed to as he or she grows. These, in turn, can impact the likelihood a student will be successful in school in both direct and indirect ways.

Low SES families are more likely to struggle to provide consistent, stable, quality health care for their children (Crook & Evans, 2014; Garcy, 2009; Holliday, Cimetta, Cutshaw, Yaden, & Marx, 2014; Ladd, 2012). Studies have shown that students who do not receive quality health care are more likely to struggle academically in school, in

particular in ELA and mathematics (Garcy, 2009; Holliday, Cimetta, Cutshaw, Yaden, & Marx, 2014). Poverty also impacts the development students through limiting access to stimulating experiences at an early age. Children living in poverty are less likely to receive cognitively stimulating experiences, such as attentive parents who frequently talk with or read to them, and are more likely to spend extend periods of time in front of the television (Dearing et. al., 2016; Holliday, Cimetta, Cutshaw, Yaden, & Marx, 2014; Ladd, 2012; Quinn & Cooc, 2015). One way this can impact a child is through the lack of development of executive function skills, such as planning, working memory, inhibition control, and attention regulation. Crook and Evans (2014) found that students from low SES families exhibited poor planning skills by third grade which resulted in poorer performances on ELA and math assessments by grade five.

Students living in poverty are also less likely to have access to a wide variety of resources or life experiences when compared with students from middle to high SES families, such as robust home libraries, computers and online access, or travel away from their home communities (Dearing et. al., 2016; Ladd, 2012; Sirin, 2005). Access to these kinds of resources and life experiences can have an effect on the knowledge and understanding a student comes to school armed with, which in turn, can be a benefit to a student. In contrast, a student who lacks these experiences and resources may find themselves automatically disadvantaged the moment they step into a classroom, especially if the instructional practices in that classroom are teacher-focused and didactic in nature. Additionally, low SES communities are less likely to have an abundance of neighborhood engagements or opportunities for students away from schools, such as parks, sports, or youth community programs (Dearing et. al. 2016; NRC, 2012; Sirin

2005). Not only can these programs serve to support students by providing help with homework or school struggles, they can also provide an outlet away from school that will direct them away from harmful risk behavior, such as drugs and alcohol (Berliner, 2006).

Among the many challenges faced by families living in poverty that can both directly and indirectly impact student achievement include food insecurity, single parent households, low parental education, inconsistent or no daycare, lost student attendance, student transiency, overcrowded homes, and existential threats such as drugs and alcohol (Berliner, 2006; Holliday, Cimetta, Cutshaw, Yaden, & Marx, 2014; Ladd, 2012; Whipple, Evans, Barry, & Maxwell, 2010). Transiency, in particular, is identified as a problem, with students leaving one school and transferring into another both during and between school sessions, often times disrupting not only academic progress, but also social and emotional connections (Geier, et. al., 2008; Ladd, 2012; Whipple, Evans, Barry, & Maxwell, 2010). Finally, families living in poverty possess less social capital than those not living in poverty (NRC, 2012; Sirin, 2005). Social capital gives parents the experience and ability to navigate the social systems and power structures within the school culture. Parents with social capital will be more empowered to advocate for the academic, social, and emotional wellbeing of their children in school.

ASSUMPTIONS, LIMITATIONS, AND DELIMITATIONS

Assumptions.

Based on the theoretical framework that informs this study, the following assumptions can be made:

- End of the year state science test data is a measurement of student achievement in science in grades 4 and 5 and, by extension, a way to determine if a teacher is potentially effective at teaching science.
- Teaching practices employed in the classroom play a major role in determining to what degree a student will be successful in science, as measured on the state's end of the year science assessment.
- Teacher beliefs inform how a teacher approaches the learning experience and can have an impact on the way a teacher views how students effectively learn science, his or her confidence in teaching science through inquiry-focused practices, and how he or she views the cultural identities of students.
- Free or Reduced Lunch status serves as a proxy for determining if a student can be identified as living in poverty.
- Students identified as living in poverty who out perform their demographic peers do so, in part, as a result of the instructional practices and pedagogical techniques employed by his or her teacher.
- Poverty plays a role in the degree to which a student comes to school prepared to learn science, both in terms of prior knowledge and life experiences, as well as in the student's cultural identity, values, norms, and priorities.
- Constructivist science inquiry practices create a context in which students are exposed to science phenomena through authentic experiences that serve as the foundation for constructing explanations of those phenomena through questioning, conducting investigations, engaging in research, analyzing data, and scientific modeling.

- Behaviorist instructional practices are grounded in teacher-centric, didactic approaches to learning science whereby knowledge is approached as a rigid thing to be assimilated and understood (Deubel, 2003, Skinner, 1989). Behaviorist instructional practices tend to favor students who come to the learning experience predisposed to be successful in such as setting as a result of their life experiences, their degree of privilege based their socioeconomic status, their personal and cultural influences concerning the nature of power structures in schools, their view of education, and the social capital they are able to wield.
- Culturally relevant pedagogies inform an approach to teaching students in a manner that helps them overcome differences between the cultural norms, values, and beliefs of diverse students and the cultural norms, values, beliefs, and power structures of the teacher and broader school system.

Limitations.

In studying the teaching practices and pedagogies of elementary science teachers who teach students living in poverty, the following limitations are considered:

- The sample of teachers and students is limited to the schools within a particular school district in a southeastern state.
- Data being used to identify grade 4 and 5 teachers who may potentially be effective at raising the achievement gap for students living in poverty is limited to the results of the end of the year state science assessment.
- The end of the year state science test scores being used to identify potentially effective teachers is based on the results of the students from the previous school

year and do not reflect the dynamics of the current group of students a given teacher is charged with teaching.

- The context in which science teaching occurs during an observation, including the topic, the size of the class, the time allocated to teaching science, and the nature of the instructional practice and pedagogies employed are unknown prior to any given observation.
- Data used to identify the instructional practices of these teachers is limited to what is observed during the observation window and, therefore, would not capture instructional practices prior to or following the observation period.
- As part of the researcher's positionality, there is a pre-existing relationship within the structure of the school district between the researcher and the teachers being observed and interviewed. Though observations are part of the routine in this relationship, interviews are not and therefore there is a potential limitation imposed on the information shared during the interview.

Delimitations

The following parameters serve as boundaries to the research and inform choices made by the researcher:

- Teachers who do not meet the criteria for observation will not be a part of this study because of the descriptive nature of this study regarding the teaching practices, pedagogies, and beliefs of those teachers who meet selection criteria. The criteria for selection includes teachers for whom 50% or more of their students are identified as living in poverty by their free or reduced lunch status and whose test scores for the class outperform the average for students living in

poverty by one standard deviation on the end of the year state science standardized test when compared with the district-wide test results.

- Teachers considered for selection will be limited to grades 4 and 5 because those are the only grades in this state for which there are end of the year state science test scores.
- Although ethnicity does have the potential to play a role in whether or not a student is living in poverty, teacher selections for observation will be based on the demographic of his or her students living in poverty (to be determined as described above) because of the potential for poverty to cross lines of ethnicity.
- Analysis of observational data will be confined to overt examples of teaching practices that reflect constructivist science inquiry practices and/or culturally relevant instructional practices because those reflect the theoretical frameworks that underlie the assumptions made in this study. Though other observed instructional practices or pedagogical techniques might be described as part of the data, they will not be considered in the analysis of the observational data.

CHAPTER 3

METHODS

Given the persistent nature of the science achievement gap among low SES students, as well as the systemic barriers to teaching inquiry-focused science in the elementary setting, it was essential to identify teachers in elementary schools who, despite these challenges, have shown a capacity to reduce the science achievement gap of their students. This made it possible to begin the process of identifying and describing the instructional practices and pedagogical techniques these teachers employ. This necessitated using state, district, and school level data to identify trends in student achievement on the end of the year state science assessment. Furthermore, this information, along with other locally gathered data, was used to identify schools and teachers who serve large numbers of low SES students. Finally, it was also essential to determine which teachers in these schools show evidence of a reduced achievement gap in their classes.

In order to identify the teaching practices, pedagogies, and beliefs held by these successful teachers in schools serving low SES populations, it was necessary to directly examine the way science instruction occurs in the classroom. It was also important to gather data about the attitudes, beliefs, and experiences that shape not only the teacher's ideas about effective science teaching practices, but also how that teacher regards her students as learners and what she feels they are capable of learning. Finally, it

was essential to gather data regarding the perceptions of the students in these classes about their experiences learning science and how students perceive the role of their teacher.

RESEARCH QUESTIONS

The following research questions informed the researcher's process of identifying, describing, and analyzing classroom practices, pedagogical approaches, beliefs, and impacts of highly effective elementary science teachers in schools serving low SES communities:

- What are the instructional practices being employed by elementary teachers in classrooms where the science achievement gap is less than predicted by school and district test data?
- To what degree do the instructional practices being employed by these elementary teachers reflect inquiry teaching practices and/or culturally relevant teaching practices with the potential to reduce the achievement gap in science?
- What do teachers feel are their most influential beliefs and experiences regarding teaching and learning science of elementary teachers in classrooms where the science achievement gap is less than predicted by school and district test data?
- What are the perceptions regarding learning science among the students of teachers who are successful at reducing the elementary science achievement gap?

RESEARCH DESIGN

Type of Study.

As the purpose of this research is to investigate the practices and attitudes of effective elementary science teachers in schools serving low SES communities, the most

appropriate approach to this study is from a descriptive phenomenological case study research perspective (Creswell, 2014). In a phenomenological descriptive study, the researcher seeks mainly to gain further insight into the nature of a problem or phenomenon through gathering data that will allow for a more detailed description of the characteristics of those engaged in the phenomenon. In this case, that problem is the persistent presence of the science achievement gap and the barriers to effective inquiry-focused science instruction in elementary schools. And the phenomenon with regard to that problem is those teachers who, despite these challenges, manage to reduce the science achievement gap of their students.

As a descriptive study, this work yields insight into the nature of effective science instructional practices and the teachers who employ them in low SES schools. While not seeking to ultimately define how to successfully overcome the science achievement gap for students living in poverty, this study allowed the researcher to identify and describe the traits, practices, and beliefs of the teachers who are successful at overcoming this achievement gap and to see how these practices and beliefs reflect the theoretical frameworks of science inquiry teaching and/or culturally relevant pedagogies.

Additionally, the researcher was able to infer to what degree the instructional decisions of the teachers are consciously informed by an understanding of one or both theoretical frameworks or if the teacher is simply “doing good science teaching” without fully realizing what it is that results in the positive impact of his/her instructional choices.

Finally, the researcher was able to explore the perceptions of the students impacted by the teacher’s instructional choices and pedagogical practices.

This study is best characterized as a mixed methods study as it seeks to combine both qualitative, descriptive data with quantitative data in order to craft a more complete, comprehensive case study of the participant teachers. In addition to the use of simple statistical methods in analyzing state and district data regarding student free and reduced federal lunch program status and student achievement on the end of the year state science assessment, additional quantitative data was collected through the use of an Instructional Practices Log for Science (IPL-S) that quantified the amount of science instructional time, topics covered, methods employed, and resources utilized. Additionally, qualitative data in the form of classroom observation data along with interview and focus group responses was used to more fully describe the characteristics of teachers, their instructional practices, insights, perceptions, and beliefs, as well as the perspectives and ideas about science education from their students. Together, both quantitative and qualitative data allowed for a broad characterization of the instructional practices and efforts of the teacher that can then focus in on detailed actions, ideas, beliefs and perceptions related to how each participant effectively teaches science.

Theoretical Research Perspective.

The theoretical perspective that informs the methodological approach to this study is phenomenology. A phenomenological philosophical approach seeks to describe and understand a particular phenomenon through the shared experiences and narratives of those engaged in the phenomenon (Cilesiz, 2009; Yüksel & Yildirim, 2015). In educational settings in particular, these can include lived experiences, perceptions, feelings, attitudes, and beliefs about a particular phenomenon (Yüksel & Yildirim, 201). In this case, the phenomenon is those teachers whose choices, actions, and beliefs result

in their low SES students overcoming the anticipated science achievement gap. This theoretical perspective suggests that the understanding and insight necessary to fully describe the phenomenon as well as seek to ascribe elements of it to the theoretical frameworks of constructivism and/or culturally relevant pedagogy can come from observing first-hand the experiences of the teacher and his/her students as well as through the perceptions of the teacher and his/her students.

Methodological Approach.

A mixed method, descriptive research methodological approach was employed in this study in order to identify and describe the instructional practices of elementary teachers who are effective at reducing the science achievement gap. This approach, grounded in a phenomenological theoretical perspective, informed the selection of research methods and analyses. When viewed through a phenomenological framework, a mixed-methods descriptive methodological approach seeks to use both qualitative observational data that will allow for the development of a detailed description of the instructional practices and pedagogical techniques evident in each teacher's classroom as well as quantitative data regarding the instructional goals, frequency and duration of science instruction, and the frequency and nature of science learning activities routinely employed and reported through the IPL-S. Additionally, this approach allows for the use of interview data as well as focus group responses to help further detail the nature of the phenomenon under study. Through this methodological approach, a case study for each teacher was constructed that fully described the choices, actions, attitudes, beliefs, methods, and impacts of what happens in the classroom. Such detailed descriptions made

it possible to consider the theoretical framework that best informed each teacher's actions and beliefs.

SETTING AND SAMPLING

Setting Description.

In seeking to identify teachers who serve in schools serving significant numbers of low SES students, as determined by eligibility for the federal free or reduced lunch program, it was necessary to select a school district that is situated in a location where such populations are present. The southeastern state in this study is a diverse state with schools that serve urban, suburban, and rural communities. The school district that is the focus of this study reflects a similar degree of diversity, with neighborhoods bordering the more urban areas of the center of the state, neighborhoods more traditionally suburban in nature, and regions within the district that share characteristics with more rural communities. This district has an enrollment of over 27,000 students, with 48% of the student population identified as living in poverty. Of the 15+ elementary schools in the district, the percentage of students living in poverty ranges from 19.7% to 89.7% (SCDE, 2016). This provided the researcher with a range of schools for which the percentage of students living in poverty would be greater than 50%.

Setting Sampling.

The researcher employed a purposive critical sampling technique to identify specific schools that meet the criteria of 50% or greater of the students who participated in the end of the year science standardized state test for grades 4 and 5 for 2017 qualifying for the federal free or reduced lunch program. Applying the criteria, the researcher was able to identify eleven schools within the district. This allowed the

researcher to then narrow the focus to individual teachers within that school that met the specific sampling criteria for participant selection.

Participant Sampling.

As the purpose of this descriptive study is to identify and describe the teaching practices, pedagogical techniques, beliefs, and attitudes of the teachers who reduce the science achievement gap among their students, it was necessary to identify individuals who teach science in elementary schools that serve low SES neighborhoods and whose students have been successful in reducing the gap in science achievement between those who qualify for the National School Lunch Program (NSLP) and those who do not. To identify these teachers, it was necessary to employ a purposeful critical sampling technique that utilized specific criteria. Prospective teachers needed to teach at schools that served a population where 50% or more of the students who participated in the end of the year science standardized state test for grades 4 and 5 for 2016-2017 school year qualified for the NSLP. Applying this criterion, the research was able to identify eleven prospective schools within the target school district. Only teachers from grades 4 and 5 were considered for this study as those are the only two grades for which there was an end of the year state science assessment during the 2016-2017 school year. From these eleven schools, the researcher then identified teachers from grades 4 and 5 for whom at least 50% of their students during the 2016-2017 school year were eligible for participation in the NSLP. The researcher further narrowed the search by identifying teachers for whom the percentage of NSLP eligible students who scored “meets expectations” or “exceeds expectations” on the state’s end of the year science standardized test score for the 2016-2017 school year exceed the district’s percentage of

NSLP eligible students who scored “meets expectations” or “exceeds expectations.”

Finally, of those teachers who meet the above criteria, the researcher identified teachers for whom 50% or more of their current science students for the 2017-2018 school year are identified as qualifying for the NSLP. Based on these criteria, twenty-one 4th and 5th grade teachers were initially identified, though it was later determined that at least two would be eligible for consideration as one of them no longer taught science and the other no longer taught either 4th or 5th grade students.

Because more than three teachers were identified through these criteria, the researcher engaged in a purposeful selection process that included examining teachers with higher percentages of students who are eligible for the NSLP during the 2017-2018 school year. Final selection also took into consideration the willingness of principals at prospective schools to allow their teacher to be a part of this research as well as the location of the schools within the district, specifically selecting schools that served different neighborhoods within the district’s geography. Of the three teachers first identified through this purposeful selection process, one of them was the teacher who was later determined to no longer teach science, although both she and her principal indicated a willingness to participate in the study. This necessitated identifying another teacher from the list of participants, one who not only met the selection criteria but also served in a school that was not in proximity to the other two. Once another potential teacher was identified, the principals of the three teachers were approached and indicated their willingness to allow their teachers to participate. These teachers were then approached and invited to participate in a study of the science teaching practices and instructional pedagogies they employ. All three teachers elected to participate in the study. For the

purposes of this study, these teachers are identified by the pseudonyms Ashley, Miranda, and Tali. Of these, both Ashley and Tali were among the original teachers considered for participation. The third teacher initially considered was a 5th grade Caucasian teacher who no longer taught science during the 2017-2018 school year. Miranda was then selected as an alternate candidate in order to fulfill the selection criteria of teaching in a school geographically removed from the other two schools. Table 3.1 illustrates how these three teachers met the selection criteria.

Table 3.1 Qualifying criteria for Ashley, Miranda, and Tali

Teacher's Name	2016-2017 School 4 th /5 th grade % of NSLP students	2016-2017 Teacher % of NSLP students	2017-2018 Teacher % of NSLP students	% of 4 th grade NSLP students at participant's School who scored Meets/Exceeds	% of 4 th grade NSLP students for Teacher who scored Meets/Exceeds
Ashley	79.9	75.0	69.0	29.5	53.3
Miranda	75.0	55.6	52.3	37.9	43.3
Tali	56.6	62.5	64.3	64.0	68.0

By comparison with these teachers, 37.8% of the 4th grade students across the entire school district who participated in the NSLP in 2016-2017 scored “Meets Expectations” or “Exceeds Expectations” on the state’s end of the year standardized science assessment.

In comparing the percentage of NSLP students who scored “Meets Expectations” or “Exceeds Expectations” for these three teachers with the 36.3% of SIP across the entire state who scored “Meets Expectations” or “Exceeds Expectations,” although the percentages in both Ashley’s and Miranda’s classes exceeded the state’s percentage, the

differences were not statistically significant, having p -values of 0.0853 and 0.2148 respectively. In Tali's class, however, the p -value was 0.0005, indicating a statistically significant difference in terms of the percentage of her NSLP students who scored "Meets Expectations" or "Exceeds Expectations" in comparison to the state's percentage.

Participant 1: Ashley, 4th Grade Teacher at Pinnacle Elementary School.

Ashley is a female African American teacher between of 40 and 50 years of age at Pinnacle Elementary School. Pinnacle Elementary School serves a suburban community with a population of over 500 students from grades Kindergarten through 5th grade, as well as small number of pre-K students. Among the 4th and 5th grade students at Pinnacle Elementary, 79.9% qualify for the NSLP. Pinnacle Elementary School is a one to one technology school. Starting in 3rd grade, all students in the school are issued an in-school laptop computer.

During the 2016-2017 school year, 75% of Ashley's students qualified for the NSLP, among whom 53.3% scored "Meets Expectations" or "Exceeds Expectations" on the state's end of the year standardized science assessment. In comparison, 29.5% of the 4th grade students who qualified for the NSLP at Pinnacle Elementary School scored "Meets Expectations" or "Exceeds Expectations." Across the entire school district, 37.8% of students who qualified for the NSLP scored "Meets Expectations" or "Exceeds Expectations."

Ashley has taught at Pinnacle Elementary School for the past ten years, though her overall experience in education, both formal and informal, spans twenty years. Ashley started in a teacher education program but switched majors part way through completing her program. She then became an interventionist and a parent educator in an

education co-op. Moving to her current state, she worked first as a day care director and then as a teacher in the county's First Steps program. She started substitute teaching and then transitioned to be a teacher's aide in the mid 2000's. Earning her Master of Arts in Teaching through an online degree program, Ashley student taught in her current district at another school before being hired to teach at Pinnacle Elementary School as a full time certified teacher. At Pinnacle Elementary School, Ashley has served as a K-5 interventionist and has taught Kindergarten and 1st prior to becoming a 4th grade teacher. She has taught 4th grade for the past five years. Ashley is a self-contained teacher, in that she teaches the four core content subjects of English language arts (ELA), math, science, and social studies to all her students. For the 2017-2018 school year, Ashley taught a class of 18 4th grade students, ages 9 to 10. Ten of her students were female and eight were male. Two of her students were Hispanic, two were Caucasian, and the remaining fourteen were African American. During the 2017-2018 school year, 69% of her students qualify for the NSLP.

Participant 2: Miranda, 4th Grade Teacher at Normandy Elementary School.

Miranda is a 25 year old female Caucasian teacher at Normandy Elementary School. Normandy Elementary School serves a suburban community with a population of over 500 students from grades Kindergarten through 5th grade, as well as small number of pre-K students. Among the 4th and 5th grade students at Normandy Elementary, 75% qualify for the NSLP. Normandy Elementary School is a one to one technology school. Starting in 3rd grade, all students in the school are issued an in-school laptop computer.

During the 2016-2017 school year, 55.6% of Miranda's students qualified for the NSLP, among whom 43.3% scored "Meets Expectations" or "Exceeds Expectations" on

the state's end of the year standardized science assessment. In comparison, 37.9% of the 4th grade students who qualified for the NSLP at Normandy Elementary School scored "Meets Expectations" or "Exceeds Expectations." Across the entire school district, 37.8% of students who qualified for the NSLP scored "Meets Expectations" or "Exceeds Expectations."

Miranda has been a teacher for three years, all of them at Normandy Elementary School. Her student teaching also took place at Normandy Elementary. She has taught 4th grade all three years, though she has only taught science for the past two years. Although during her first year, she taught ELA and social studies, for the past two years, Miranda has been a self-contained teacher, in that she taught the four core content subjects of ELA, math, science, and social studies to all her students. For the 2017-2018 school year, Miranda taught a class of 16 4th grade students, ages 9 to 10. Ten of her students were female and six were male. One of her students was Hispanic, six were Caucasian, and the remaining nine were African American. During the 2017-2018 school year, 52.3% of her students qualified for the NSLP.

Participant 3: Tali, 4th Grade Teacher at Grissom Elementary School.

Tali is a 31 year old female African American teacher at Grissom Elementary School. Grissom Elementary School serves a suburban community with a population of over 600 students from grades Kindergarten through 5th grade, as well as small number of pre-K students. Among the 4th and 5th grade students at Grissom Elementary, 56.6% qualify for the NSLP. Grissom Elementary School is a one to one technology school. Starting in 3rd grade, all students in the school are issued an in-school laptop computer.

During the 2016-2017 school year, 62.5% of Tali's students qualified for the NSLP, among whom 68.0% scored "Meets Expectations" or "Exceeds Expectations" on the state's end of the year standardized science assessment. In comparison, 64.0% of the 4th grade students who qualified for the NSLP at Grissom Elementary School scored "Meets Expectations" or "Exceeds Expectations." Across the entire school district, 37.8% of students who qualified for the NSLP scored "Meets Expectations" or "Exceeds Expectations."

Tali has been a teacher for seven years. Her first four years as a teacher were at a school in another school district where she taught 5th grade. For the past three years, she has been a 4th grade teacher at Grissom Elementary School, though she has only taught science for the past two years. During the 2017-2018 school year, Tali taught science and mathematics to two different sets of students as part of a team where a different teacher taught the same students ELA and social studies. One of these two classes was identified as the target class for the purposes of this study. For the target class, Tali taught 21 4th grade students, ages 10 to 11. Eleven of her students were female and ten were male. All 21 of her students were African American. During the 2017-2018 school year, 64.3% of her students qualify for the NSLP.

DATA COLLECTION

Methods.

As a mixed-method, descriptive study into the instructional practices and attitudes of these teachers, the researcher collected data through a variety of methods in order to assemble a detailed case study for each teacher participant.

Observation Methods.

In order to identify and describe the instructional practices and pedagogical approaches employed by the participants, each teacher was observed at least three times during the course of the study, with each observation lasting for the duration of the science lesson. Because the researcher felt that data saturation was achieved for each teacher, it was not necessary to conduct additional observations.

The researcher coordinated with each teacher to determine the scheduling of each observation, though not the exact nature of the observation in terms of content or sequence within the instructional unit. This was done by asking the teacher to allow the researcher to observe what they consider a model lesson that showcased their science inquiry teaching skills and practices. Each observation was video recorded so that instructional practices and pedagogical techniques could be coded and thoroughly described. The researcher obtained permission from the teacher, the school, and the parents of the children prior to the onset of the observations. Additionally, the researcher provided the teacher with a confidentiality agreement to protect her identity and the identities of his/her students as per IRB and district policies.

Observations were described and coded for evidence of the following constructivist science inquiry elements:

- Presence of question-driven investigations, problems, and explorations.
- Student generation of authentic data through investigations
- Analysis and use of data from investigations to support inferences and claims
- Student-constructed explanations of processes and phenomena
- Student-communicated reasoning, claims, inferences, and explanations

- Development and use of student-generated models of scientific phenomena

Observations were also described and coded for evidence of the following culturally relevant pedagogical elements:

- Teacher communicates, verbally and/or in writing, high academic expectations for all students
- Evidence of student centered and student focused learning
- Learning executed as a knowledge-building experience (as opposed to knowledge memorization)
- Flexible use of instructional practices responsive to student characteristics
- Contextual elements include culturally familiar and meaningful characteristics
- Inclusion of culturally meaningful social justices or advocacy elements

In addition to video recording the occurrence of science instruction, during classroom visits, the researcher employed a descriptive observation framework with each element operationally described (see Appendix A). Additionally, the researcher recorded detailed field notes of the observation in order to describe details that the recording might not have fully captured as well as to provide data saturation and act as a reliability check for the observational data. Through a combination of coding and describing the elements witnessed in each classroom observation, the researcher was able to both determine the presence of the different elements as well as provide details about the exact nature of those elements as they occurred in the instructional context.

Instructional Practices Log for Science.

In addition to directly observing instruction, the participant teachers also employed an online Instructional Practices Log for Science (IPL-S) in order to capture an

accounting of the various elements of science instruction that occur on a daily basis (Adams, et. al., 2017). The IPLS is a “daily teacher log designed to measure K-5 teachers’ enacted science instruction focused on five dimensions including high-level sense-making, low-level sense-making, communication, basic practices, and integrated practices” (Project ATOMS, 2017). This instrument requires teachers to complete an online log that identifies the attributes of their science teaching each day over a 45 day period, including whether or not science was taught, for how long, the content covered, the nature of the activities, and the nature of any materials or resources that were used (see Appendix B). At the beginning of the data collection period, prior to the initial observations, the researcher trained the participant teachers on the use of this log and provided them with a hard copy of the log to help guide its use. The data collected through this log helped to create a more complete picture of the routine science instructional practices that each teacher engaged in and allowed for a cross referencing with observational data as well as interview results that allowed the researcher to construct a more complete picture of the each participant’s routine science instructional choices and actions.

Interview Methods.

In order to gather evidence of the teacher beliefs and attitudes about teaching science in a high poverty school, the researcher conducted a semi-structured interview with each individual teacher participant. Each interview took place after all observations have been conducted for a given teacher. Each interview was recorded and transcribed for analysis.

In addition to gathering basic profile information about the participant (gender, age, grade currently teaching), each interview included the following questions:

- How many years of experience do you have in teaching, both in total and in your current grade?
- What schools and districts have you taught in over the course of your career?
- In terms of the community and students served, how would you describe the schools you have taught at, including your current school?
- What was your preservice science teaching preparation experience like?
- Please describe the most meaningful, if any, science professional development you have experienced since you started teaching? Why was it meaningful?
- What has been your professional development experience with regard to the state's new standards and the science practices that are part of those standards?
- Please describe any form of training you have experienced to support teaching diverse student populations, either as preservice or through professional development?
- How have you implemented the knowledge and skills gained from these professional development experiences in your class and with your students?
- How do your past experiences with other schools compared with your current experience here?
 - if the participant taught at another school and/or in another district.
- How do you feel about teaching science?
- What would you say are your strengths and weaknesses in teaching science content?

- How would you describe your approach to teaching science?
- How would you describe the way you assess student understanding of the science you teach?
- How often do you teach science during a quarter? When you teach science, approximately how many minutes of your day are used for teaching science?
- How do you think students best learn science?
- How would you describe your students, in general, with regard to their ability to learn science?
- Describe any strategies or techniques you use to help students better understand science.
- Describe any strategies or techniques you use to differentiate the way you teach science to students with different backgrounds, needs, or learning styles.
- Describe any strategies or techniques you use to make sure all students are engaged in learning and that all student voices are represented within your classroom.
- Describe any strategies or techniques you use to help connect your students with what you are teaching in science and to make it personally relevant to them.
- What role, if any, do the families of your students play how your students learn science?
- What would you say are some of the challenges you encounter when teaching science to your students?
- Please describe your most memorable, positive experience teaching science and why you consider it such a positive experience?

As necessary based on the individual responses to these questions, the researcher asked follow up questions for clarity or to probe deeper based on specific participant responses. Additionally, the researcher asked specific, individual questions based on analysis of the three preceding classroom observations. These questions were used to gather additional insight into the practices and instructional techniques witnessed during the observations in order to help clarify researcher inferences regarding the reasoning behind the specific occurrence. The additional questions for each of the three participants are listed as follows:

For Ashley, the following additional questions were asked:

- When you teach science, you frequently ask your students questions. What is your reason for doing this?
- When you teach science, you mention the “language of science.” Why do you do this?
- What do you consider your role (as the teacher) to be when teaching science?

For Miranda, the following additional questions were asked:

- What role do you think you, as the teacher, play in teaching science?
- What was behind your decision to select the curriculum resource you used for your mimicry lesson?

For Tali, the following additional questions were asked:

- What role do you think you, as the teacher, play in teaching science?
- What is the purpose behind the way you use questions in your class?

Focus Group Methods.

To gain insight into the student feelings about and perceptions of the participating teachers' science teaching practices and interactions with his/her students, the researcher conducted three student focus group interviews with students selected from each of the participating teachers' classes. The teacher was asked to select four to six students who would represent a cross section of their class in terms of gender, ethnicity, and socioeconomic characteristics. The focus group interviews took place after all three observations were conducted for each teacher. As with the interviews, the focus group questions were recorded and transcribed.

The following questions were asked during the focus group:

- What do you think about the way your teacher teaches science?
- What is something you enjoy about learning science in your class?
- What is something you do not enjoy about learning science in your class?
- What is something you like about your teacher?
- Do you think your teacher believes you can learn science? What makes you say that?
- Do you feel like you a part of the classroom community during science? What makes you say that?
- How does your teacher help you connect with what he/she is teaching about science?
- What is one thing you would change about your science class if you could?

In conjunction with these questions, the researcher asked follow up questions that were necessary for clarity and/or to probe deeper based on specific responses.

DATA ANALYSIS

A descriptive analysis of the data gathered from classroom science teaching observations, interview responses, and focus group responses was used to construct a narrative describing the teaching practices, pedagogical beliefs, and impacts for each teacher participant. Classroom observations were analyzed for the occurrence of elements that reflected the defining characteristics of science inquiry practices and culturally relevant pedagogy and were initially coded using twelve elements of the descriptive framework (Appendix A). Each specific coded occurrence was described, using both the video observation and any notes about the element from the researcher's field notes. Coded elements and descriptions were then analyzed through framework characteristics of both science inquiry practices and culturally relevant pedagogy to describe the how the teachers' practices reflected one or the other or both theoretical frameworks.

IPL-S results were analyzed to look for trends in the type, frequency, and nature of science instructional practices each teacher employed, as well as to capture nature of the teacher's learning goals, use of different resources, and frequency and duration of science instruction to extend the snapshot of teacher actions and practices beyond the scope of the observations. This analysis was carried out through simple statistical descriptions. Mean, median, and mode were calculated for the duration of science instruction as reported over the course of the reporting period. Frequency and percentage of different learning goals and instructional resources were also calculated. Finally, the occurrence and frequency of the teacher-reported science activities was reported and broken down by how these activities were classified as defined by the IPL-S into one of the following types: low sense-making, high sense-making, communication, basic

practices, integrated practices, and non-defined. In addition to providing a broader description of each teacher's practices, the data serve as a check on the inferences made from the observational data regarding science instructional practices because it encompasses a much greater span of time. Finally, when compared with the interview data, the IPL-S data allowed the researcher to compare the beliefs and intentions of each participant with the execution of science instruction on a routine basis.

Interview data, both from individual teachers and focus groups, were recorded, transcribed, coded, and analyzed to look for emerging themes and trends in how the participants respond to the prompts regarding their perceptions, attitudes, and beliefs about teaching inquiry-driven science and their feelings about the capabilities of their students and how their students best learn science. Additionally, the researcher analyzed data from interview responses in the context of the data from the observations to ascertain if the participating teacher's self-described beliefs and reasoning for their actions matched their actions and outcomes as observed in the classroom. Participant data from different interviews was initially analyzed individually, then themes from each interview were compared across all three participants to examine how their experiences, attitudes, and beliefs about science might influenced the way they engage in science instruction with their diverse students.

Data from the focus group interviews were compared with data from the corresponding teacher to compare the attitudes and actions of the teacher with the attitudes and perceptions of that teacher's students with regard to learning science. Together, these data were used to construct a descriptive narrative of each participating teacher to determine how the instructional practices, pedagogical approaches, and beliefs

of each teacher aligned to the defining characteristics of constructivist science inquiry, culturally relevant pedagogy or both. Additionally, from this analysis, the researcher was able to make inferences based on that alignment for how and why the outcomes of the students of these teachers with regard to science achievement showed a reduced difference when compared to students of teachers who teach fewer numbers of students identified as living in poverty based on eligibility for the NSLP.

Reliability and Validity.

To address issues of reliability, the researcher used consistent methods of data collection throughout every step of the study. The use of video recorded observations in conjunction with observer field notes helped establish congruence between what was recorded and what was verbally described. Additionally, the researcher operationally defined each of the twelve elements that are the hallmarks of both constructivist science inquiry and culturally relevant pedagogy and used these defined and described elements in coding and analysis of their presence during observations. This helped to ensure that the same method of identifying and describing the elements present during an observation is being applied across all observations. A similar approach was taken with both the teacher interviews and the focus group interviews. In addition to audio recordings of each session, the researcher kept written notes during the interviews. Furthermore, with the exception of any spontaneous follow up or clarifying questions, the same questions were used in all three semi-structured interviews to ensure consistency in data gathering.

To address issues of validity regarding the observational data, data were analyzed through the lens of the twelve descriptive, operationally defined and described elements being used to code the observations. These twelve elements are based on specific

characteristics defined by the theoretical frameworks of constructivist science inquiry teaching and culturally relevant pedagogy as being the hallmarks of each instructional approach. Therefore, when an element was described and coded, the process of coding was accurate in how it aligns the described occurrence with a specific characteristic from the theoretical framework. A code book was developed to describe these elements and used during data analysis to ensure consistency of application. Validity with regard to the teacher interviews was maintained through member checking, whereby after the researcher completed his analysis of the interview data, it was shared with the three participant teachers in order to ensure that the researcher's interpretations and inferences were valid and accurate. Additionally, an initial draft of each participant's descriptive case study was shared with the teacher to see if they agreed with the narrative. In response to the member checking, all three participants read their individual narrative sketches and responded, indicating that they agreed with the descriptions and interpretations the researcher presented.

Finally, the use of the IPL-S allowed for a cross-check of routine teacher actions with the inferences made from both the observations and the interview as well as a comparison of teacher beliefs with teacher actions. This helped to determine the degree to which the instructional practices directly observed by the researcher were the norm for each given teacher as recorded on the IPL-S.

POSITIONALITY

Role of the Researcher.

The role of the researcher as both a science educator and the K-5 science content specialist in this school district for the past eighteen years served to strengthen the study

in the several ways. Having an established relationship with the participants with whom the researcher has worked to engender a sense of support and trust, there exists a sense of trust and positive rapport that transferred to the work in this study. Additionally, the researcher's work on the final draft for the state's current science standards and the support documents for the science practices aligned with those standards helped to demonstrate the researcher's knowledge of scientific inquiry and science content as well as foster a sense of confidence and trust with the participants, despite the researcher's position as an outsider in the classrooms. Furthermore, having worked directly with teachers across this district to support their efforts through observations, coaching, and professional development, the participants were already aware of the researcher's identity as a non-evaluative science education professional.

Despite the researcher's significant content and conceptual knowledge of science and inquiry practice and despite efforts at establishing a rapport with the teachers, there were two significant ways in which the researcher's positionality may have hampered this study. As a result of the researcher's position in the school district, there may have been a lingering perception of administrative authority over the teachers, despite the non-evaluative nature of the researcher's professional role in the district. Additionally, during the interview process, participants may have felt compelled to provide the researcher with responses they thought he wanted or that would have cast them in a favorable light. In this way, there was the potential for a limited lack of trust that might have manifested in how they reported their perceptions, attitudes, and feelings about teaching science and their students. Furthermore, in reflecting on their attitudes about inquiry-driven science teaching and their feelings about their students as learners, it was possible they would

communicate what they thought the researcher wanted to hear as opposed to the realities of their circumstances. However, between the different methods of data collection and analysis and the positive qualities that come from the researcher's pre-existing relationship with the participants, the research was able to reduce the impact of these variables as was able to collect valid, reliable data. As a result, the researcher found no evidence that these variables hampered the data collection, data analysis, or interactions between the researcher and the participating teachers during the study. Furthermore, had the observed classroom experiences been anything other than evidence of common place practices, the reactions and interactions among the students would have shown evidence of unfamiliarity or awkwardness that was not apparent in the observations. Also, the genuine responses of the students regarding their perceptions of what learning science was like with these teachers supported the assertion that the nature of the science lessons and the practices observed were the norm in these classes.

Trustworthiness.

In order to monitor the impact of the researcher's subjectivity and positionality throughout the study, a variety of different strategies were used. The researcher conducted an audit trail in order to account for the various methods and procedures employed in data collection and analysis, as well as any major decision points and the reasoning behind these decisions. The researcher also used triangulation and engaged in data saturation through an abundance of data in the form of interview results, focus group results, audio recordings, interview notes, observational data, video recordings, researcher field notes, and the results of the IPL-S. Using member checks, the researcher

was able check for bias with regard to inferences about teacher decisions and actions by cross referencing them with the teacher's own perceptions.

CONCLUSION

Ethical Issues.

There were no ethical issues with this study. All participants, regardless of experience or school, were accustomed to classroom observations conducted by various individuals in a variety of roles, including the researcher. Additionally, the students in this district were accustomed to classroom visitors and observers. This minimized the likelihood that the presence of the researcher would be a source of distraction or disruption. Furthermore, all the participants were volunteers and were asked the same questions and observed using the same instrument and methods, ensuring that all were treated the same way.

In accordance with IRB policies, teacher participants were asked to sign an informed consent and privacy form that articulated all of the methods involved in the collection and analysis of the data as well as how identities would be protected and data would be secured. Parents of the students involved in the classroom observations were also asked to sign similar informed consent and privacy form. This form also included a place for parents to indicate if they were willing to allow their child to be considered for participation in the focus group.

At the request of two of the participating teachers, Spanish language translations for the parent permission letter and the student assent form were provided.

Copies of these forms are presented in Appendix C.

Risk and Benefit.

There were two potential risks associated with this study. First, related to the researcher's positionality, because the participants are teachers with whom he has worked in the past, there is a perception of authority that might have existed, even though the researcher does not have any direct authority over any of these teachers and supports them in a purely non-evaluative role. Teachers might feel that if their observations or responses reflect poorly on them, their school, the district, or their students that the researcher might have reported this to their principals. To address this concern, the researcher used confidentiality statements to assure participants that any data collected from the research study would be privileged information that would be protected and not shared with others beyond its inclusion in the study. Furthermore, pseudonyms were employed so that individual teachers, students, and schools cannot be identified from the outcomes of the research. A copy of this confidentiality statement is presented in Appendix C.

The other potential risk might have come from the use of students as sources of data, both through classroom observations and as focus group participants. As this involved recording classroom interactions between teachers and students as well as student responses to focus group questions, it was necessary to obtain informed consent from the parents of these students. Furthermore, as with the teachers, pseudonyms were used to so that individual students and teachers cannot be identified from the research.

Despite these risks, significant benefits were gained from this study. In identifying and describing the instructional practices and pedagogical approaches of these highly effective teachers, the researcher gained insight into ways other elementary

teachers can help their students living in poverty reduce the science achievement gap. This information can be useful in helping identify teachers who share similar characteristics and instructional approaches so that other teachers can observe and learn from them. Furthermore, from this insight, professional development and teacher preparation efforts can be reviewed and revised to include examples of these practices and explanations for how these pedagogical approaches can impact student achievement in low SES schools.

Limitations/Considerations.

One significant limitation of this study is the voluntary nature of the data acquisition experience. Although this was not the case, because the teacher participants were volunteers to the research, they might have declined to participate considering the concerns related to the researcher's positionality within the school district. Furthermore, as described above, the researcher's positionality may have resulted in inaccurate or guarded responses to the interview and focus group questions. Although this has the potential to result in any inferences made from those data being called into question, the research did not detect any evidence to suggest that the participants were providing guarded or contrived responses or that what was observed in the classrooms was anything other than the genuine, routine science instruction that commonly took place with the students of these teachers.

Finally, although the goal of this study was to seek an understanding of the perceptions, attitudes, and beliefs of different teachers, recognizing that these differences are significant and important, it is possible that others may seek to make generalizations

about all elementary science teaching and teachers in schools that serve low SES communities.

CHAPTER 4

DATA ANALYSIS

There is a persistent gap in elementary science achievement with regard to students living in poverty (Curran & Kellogg, 2016; Quinn & Cooc, 2015). Student success in science in schools serving low socioeconomic status (SES) communities can be influenced by various factors, including limited life experiences, limited health care, generational poverty, lack of resources at home, neighborhood economic segregation, and lack of instructional resources at schools receiving limited funding (Crook & Evans, 2014; Garcy, 2009; Morgan, Farkas, Hillemeirer, & Maczuga, 2016; Sirin, 2005). Additional factors that can influence student performance in science, especially in the elementary setting, can include a lack of science content or science pedagogical knowledge among teachers, limited teacher experience and understanding with science inquiry teaching methods, and a lack of support for teaching rigorous, inquiry-based science as a result of the prioritization of other content, such as English language arts (ELA) and math (Mensah, 2010; Sandholtz & Ringstaff, 2013). Despite these challenges, studies have shown that an inquiry-driven approach to teaching science can have a positive impact on student success (Santau, Maerten-Rivera, & Huggins; 2011). Additionally, teachers who employ elements of culturally relevant pedagogy (CRP) have also demonstrated that students from traditionally under-represented groups can be successful in achieving success in school (Grimberg & Gummer, 2013; Laughter &

Adams, 2012). Studying elementary teachers with a history of success teaching students living in poverty (SIP) will help to identify practices and pedagogical approaches employed by these teachers, as well as attitudes and beliefs held by them, in order to determine the degree to which their teaching reflects the defining characteristics of both science inquiry teaching and CRP that have been demonstrated in the past as successful approaches to helping low SES students succeed in elementary science. Additionally, by looking for evidence of both science inquiry practices and CRP, this study will identify the intersection at which these two approaches occur in order to illustrate the impact teachers can have when elements of both are present.

In this chapter, an analysis of the data obtained throughout the study is presented in the following manner. For each participant, a brief description of the characteristics of the teacher's school as well as a brief background about the teacher, including how she met the selection criteria, is provided. This is followed by a description of the teacher's classroom, along with an analysis of the characteristics of the classroom that exemplify elements of constructivist science inquiry and culturally relevant pedagogy. Next a detailed overview of the nature and sequence of the classroom observations is presented. The data collected from the IPL-S and the classroom observations are analyzed for the presence and potential impact of elements of science inquiry practices and CRP. The results of the interviews are analyzed for evidence of how each teacher's attitudes, perceptions, and beliefs about teaching science in a low SES school setting reflects elements of constructivist science inquiry and CRP. Finally, the results of the focus group interviews from the students of each teacher are analyzed for how the students' attitudes

and perceptions of learning science and of their teacher compare with the science learning perceptions and attitudes of that teacher.

Following the analysis of each individual teacher, the occurrence of different elements reflective of constructivist science inquiry practices and CRP are compared across all three teachers to determine trends and patterns that may be consistent among the participants as well as to identify isolated characteristics unique to individual teachers.

DEFINING CHARACTERISTICS

In order to engage in the analysis of teacher practices, pedagogical influences, attitudes, beliefs, and impacts, it is first necessary to clarify the defining characteristics of science inquiry teaching and CRP.

Defining characteristics of science inquiry teaching.

Science is more than just a body of knowledge that represents the current scientific understanding of the physical universe; it is a set of inquiry practices that scientists engage in to construct, extend, evaluate, and refine that scientific understanding (NRC, 2012). And while different dimensions of science engage in a variety of different practices and approaches to how this knowledge is developed, there are a core set of inquiry-based cognitive, social, and physical practices that are common to all areas of science. As laid out by *A Framework for K-12 Science Education* (NRC, 2012), these include the use of data and evidence to develop and support claims, the engagement in analysis and argumentation to connect evidence to science concepts through reasoning, the development of scientific models to represent and test phenomena, and the development of scientific ideas through collaboration with other scientists in a social

context. These practices are distilled through the *Framework* into eight science and engineering practices (SEP) that form the performance expectations for how science learners can participate in the inquiry-based practices common across all disciplines of science in order to engage in authentic sense-making and knowledge-constructing processes that are at the core of how science operates as a discipline (NRC, 2012). These SEPs are:

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

It is important to note that it is not necessary for students to engage in every single SEP for a learning experience to be considered inquiry-driven in nature. During a given learning experience, students may only be engaged in the act of planning out an investigation or collecting data or reasoning with evidence to support a claim. It is also important, however, to understand that when students engage in these practices, it should not be done in isolation or with the sole purpose of learning about the practices. For a learning experience to be considered inquiry-driven, the use of such practices must be authentic in nature and done in the context of exploring or investigating some scientific phenomenon. Otherwise, students would simply be doing hands-on science for the sake

of doing something hands-on without truly developing a conceptual understanding of the phenomenon they are engaged with (Akerson, et. al., 2009; Haefner & Zembal-Saul, 2004; Kim & King, 2012; NRC, 2012).

Engaging in the SEPs alone is not sufficient for something to be considered inquiry-based. What makes the process of science learning inquiry-driven is when students engage in these authentic practices with the goal of developing an understanding of some science concept or phenomenon through experiential learning (Kim & King, 2012; Passmore, Stewart, & Cartier, 2009; Wu & Hsieh, 2006). To put it another way, science learning can be considered an inquiry-driven experience when students encounter a phenomenon through the lens of these practices as part of a process of exploration and discovery whereby new ideas emerge from the experience, are developed, challenged, and ultimately integrated into a schema of prior knowledge that itself evolves as a result of the incorporation of this new knowledge (Braaten & Windschitl, 2011; Cavagnetto, Hand, & Norton-Meier, 2010; Watters & Diezmann, 2007; Windschitl, 2002).

This connection between student actions and the use of authentic SEPs in the process of knowledge-building is reinforced when the teacher models and communicates an expectation of science-rich vocabulary in the classroom. By employing science-specific terms as a matter of routine communication, both by modeling them and by communicating the expectation of their use, the teacher is inviting the students to assume the role of scientists in the learning process. In this way, students are able to see themselves as active participants in scientific endeavors as opposed to passive observers to scientific phenomena. The use of science-rich language effectively invites the learner

to become a member of the authentic science culture the teacher is creating in the classroom (Townsend, Brock, & Morrison, 2018).

Given that this process of sense-making and knowledge construction takes place in the context of social interaction, dialogue, discussion, and argumentation, there is also a strong connection between the elements of science learning through inquiry practices and a social constructivist approach to learning. (Chiatula, 2015; Faircloth & Miller, 2011; Tippett, 2009; Vygotsky, 1978). In particular, the connections between science inquiry and social constructivism are strongest where learning in both contexts is viewed as a social enterprise where learning occurs through authentic practices, often through the investigation or application of real-world scenarios, with the goal of knowledge construction in which the teacher sets the conditions for learning to occur but does not assume the traditional role of knowledge authority (Brophy, 2010; Bryant & Bates, 2015; Doolittle, 2014; Tippett, 2009).

In the context of these characteristics of science inquiry learning, when analyzing the data, the researcher considered the following characteristics as emblematic of an inquiry-driven science learning experience:

- Students engaged in one or more of the eight SEPs.
- The teacher creates a science-rich learning environment, including modeling the use of science-rich language and communicating the expectation of its use as a matter of routine.
- Science learning through the SEPs was social in nature with an emphasis on collaborative sense-making through discussion, reasoning, and/or argumentation.
- Science learning was sequenced so that students explored some scientific

phenomenon through the use of one or more SEPs with the goal of developing an understanding of the phenomenon.

- The teacher assumed the role of facilitator of the scientific exploration.

These last two points are in contrast to an approach to teaching science either driven by a behaviorist-informed didactic method, whereby science content is considered a rigid body of knowledge to be memorized and accepted at face value or where students might engage in authentic science practices, but only with the goal of verifying or validating something the students have already been taught about the scientific phenomenon through more traditional, didactic instructional methods (Deubel, 2003; Park Rogers, 2009; NRC, 2012; Skinner, 1989).

Defining characteristics of culturally relevant pedagogy.

Teachers who employ an approach to teaching informed by CRP work to create a supportive, inclusive learning environment where students are able to see themselves as members of a learning community that is familiar to them, reflecting many of the same values and priorities that they hold, focused on problems and challenges that are reflected in their own community (Brown & Crippen, 2016; Grimberg & Gummer, 2013; Ladson-Billings, 1995; Phelan, Davidson, & Cao, 1991). In so doing, the metaphoric barrier between the classroom culture and the student's culture is broken down and the gulf between the teacher and the learner is closed, allowing the student to feel more comfortable in the learning environment (Grimberg & Gummer, 2013; Lee, 2004). This, in turn, empowers the student to be willing to take the risks inherent in the learning process because he or she sees a relatable connection between what is going on in the

classroom and what is important in their lives (Faircloth & Miller, 2011; Grimberg & Gummer, 2013; Lee, 2004; Oldfather, 1993).

A teacher creates this environment by engaging the students in a way that affirms the culture of the learner, communicates high expectations while at the same time empowering the students to be able achieve those expectations, makes concrete connections between the concepts being taught and the values and concerns that are important to the members of the community represented by the students, and recognizes that knowledge is not rigid but constructed through shared experiences and social interactions (Ladson-Billing, 1995; Laughter & Adams, 2012; Grimberg & Gummer, 2013; Oldfather, 1993). This last characteristic, in particular, illustrates how elements of CRP overlap with elements of a constructivist-informed approach to science inquiry teaching.

In examining the work of others with regard to the elements of CRP, several common characteristics emerge. Teachers who practice CRP will often create an atmosphere of equity and shared ownership in the learning, often through collaboration and cooperation. This is often demonstrated through positive classroom relationships that exemplify care, respect, high expectations, and a belief in the ability of the students to achieve those expectations. Additionally, these teachers might also foster a positive attitude toward their learning by demonstrating relevancy and offering choice in the learning experience. Often these relevant connections are made through fostering connections between school and community. Students in these settings will engage in rigorous, higher-order thinking and inquiry-based learning in which student voice and ideas are demonstratively valued and where students shared the role of being the creators

of new knowledge (Brown & Crippen, 2016; Ladson-Billings, 1995; Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995).

Teachers who engage in CRP practices can often engage students through making connections between the science they are learning and problems and concerns that are taking place in their community. One way this can be done is to have the learning centered on a problem within the community, such as pollution, health care concerns, impact of poverty and limited resources, and to connect the science concepts the students are learning to how they can use that information to address, raise awareness, propose solutions, or take steps to solve those problems. Making social justice and advocacy central themes of the learning is a way to engage the students in the experience by connecting to their values and personal and community cultures (Brown & Crippen, 2016; Laughter & Adams, 2012; Powell, Cantrell, Malo-Juvera, & Correll, 2016).

In the context of these characteristics of CRP, when analyzing the data, the researcher considered the following characteristics as emblematic of learning experience informed by culturally relevant practices and instruction:

- Student identity and voice was valued by the teacher.
- The teacher communicated high expectations and affirmation to her students.
- The teacher made relevant connections between the content and her students.
- The teacher fostered a connection between what was going on in class and the families of her students.
- Students were given choice in their learning.
- The teacher created a positive, risk-free learning environment
- Learning includes elements of social justice and connections to community needs.

- Learning was sequenced so that students engaged in some phenomenon through with the goal of developing an understanding of the phenomenon.
- Learning was social in nature with an emphasis on collaborative sense-making through discussion, reasoning, and/or argumentation.
- The teacher assumed the role of facilitator of the learning experience.

It is noteworthy that these last three characteristics are essentially identical to two of the defining characteristics of a constructivist-informed approach to science inquiry teaching.

LESSON OBSERVATIONS

While describing the observed lessons, the researcher frequently uses the term “performance feedback.” The researcher considers this the act of providing abundant, immediate, and specific feedback that helps to either maintain or redirect effort. This can be provided both through statements to direct student attention or suggest avenues of work as well as posing clarifying questions designed to redirect students to consider what they are working on. It is primarily administered while students are engaged in active learning.

Participant 1: Descriptions of Observed Lessons.

During the study, three of Ashley’s science lessons were observed. All three lessons occurred during what was the 3rd nine-week quarter of the school year at Pinnacle Elementary School.

Observation 1.

The focus of the first observed lesson was on the parts of the plant, specifically the characteristics of the seed, and the daily objective displayed on the board stated: “I

can understand the structure of the plant as they grow from their own seed.” The lesson began with Ashley asking students questions about plants and science terms related to previous lessons (“Where do seeds come from?”; “What is an adult plant called?”; “What does survive mean?”; “Roots?”; “What are leaves?”; “What does contrast mean? This is ELA.”; “What does compare mean?”; “Plant offspring is what?”). The purpose of these questions was to activate prior knowledge before beginning their investigations. This was followed by her starting a KLEWS (Know, Learn, Evidence, Wonder, Science vocabulary) with the following focus questions: “What are seeds?” and “Where do seeds come from?” She used these questions to get her students to begin to share what they already felt they knew about these topics.

Following the chart, Ashley informed the class that they would begin their exploration about seeds working in groups. She gave each group of students a set of cards with pictures of seeds and mature plants. Students worked collaboratively to match which seeds they thought came from which plants. During this activity, Ashley moved throughout the room, checking in at each student group, asking questions (“Is that a seed?”; “Are all seeds the same?”; “Why can you tell that’s a pumpkin seed?”), and providing performance feedback (“I like how y’all sorting out seeds first.”; “Do think that’s a seed? Look at it.”; “Look at the shape it.”). After the groups had completed this task, she called their attention to the board where she showed them the correct pairings.

Next Ashley transitioned the class to a seed-sorting activity where students were given trays and a collection of different seeds. Students worked collaboratively to decide on the characteristics they would use to sort them. Following this activity, Ashley distributed a worksheet on which the students graphed the data they had collected when

sorting and counting seeds. During both parts of this activity, Ashley moved throughout the room, occasionally asking questions (“Are there any evidence there?”) and providing performance feedback (“So let’s think about what else do we wonder?”; “Let’s talk about our evidence.”). Finally, Ashley directed each student to decide which seeds they wanted to plant as part of a future investigation involving plant life cycle stages. Students prepared seeds for this by placing them in plastic zip-top bags with wet paper towels. After collecting the bags, Ashley asked the students if there was anything they had learned that they felt they could add to their KLEWS chart. She drew this lesson to a close with a teacher read-aloud of the book *Tiny Seed* by Eric Carle, during which she pointed out connections between seeds and the life cycle of plants. Finally, she asked her students to revisit the KLEWS chart one more time to add any information they felt they learned to the chart.

Observation 2.

The focus of the second observed lesson was on plant and animal characteristics, specifically acquired versus inherited traits and behaviors, and the daily objective displayed on the board stated: “I can understand inherited traits and learned behavior of organisms.” The lesson began with Ashley instructing the students to sit on the floor in front of the interactive white board. She then explained that the day’s lesson was on distinguishing between inherited and acquired traits and behaviors. She then asked her class share out what they felt they already knew about the terms inherited, learned, behavior, and traits (“What are characteristics of organisms?”; “How do we want to define characteristics?”; “What do you think learned behaviors are?”). As her students shared their prior knowledge, she would ask clarifying questions, restate and paraphrase

what they had said, and write it on the board (“Anything you want to add?”; “How do you want me to write that?”). Following this, she showed them a prepared video about the differences between inherited and acquired characteristics. During the video, Ashley frequently paused and asked the students to draw connections between what was presented in the video and what they had already shared from their prior knowledge. She indicated when a point made in the video aligned with some piece of prior knowledge the class had already shared (“So inherit, you got traits coming from family. So we can pretty much say that was accurate.”; “So those are behaviors that are learned and not inherited. Did we pretty much say that?”).

Following the video, Ashley described the directions for the different activities they would be doing through the lesson. These activities were set up as five stations at different tables with students moving in groups from station to station until each group had rotated through all five stations. Students were broken into groups and then Ashley gave the directions for each station as follows. At one station, students worked collaboratively to sort a stack of cards with pictures and descriptions of traits or behaviors based on whether they should be classified as inherited or acquired. At the next station, students worked collaboratively to sort pictures of different plant seeds into plant groups based on based on the seed’s appearance and the adult plant’s appearance. At the third station, students were given a short science story that related to the topic of acquired behavioral traits. After reading the story, they independently answered questions related to the passage.

The final two stations were similar in nature. At one station, students worked collaboratively to compare different types of fruit and attempt to determine which ones

belonged to the same type based on pictures of the outside appearance of the fruit. The final station was similar, except that at this station, the students used pictures of the insides of the same types of fruit as the previous station. Except for the reading station, at each station the students in each group worked collaboratively and discussed among themselves their reasoning for their classifications or for how they sorted the cards or pictures. During the lesson, Ashley moved throughout the room, checking in at each group, asking questions (“A snake sheds its skin. Is that learned or inherit?”; “Are there any others that you would put with citrus?”) and providing feedback (“Look at the leaves. Look at the flowers. We’re talking about characteristics.”).

After each group had rotated through all five stations, Ashley drew the lesson to a close by asking students to share some of the decisions they had made at the various sorting stations and the reasoning behind those decisions. She ended the lesson with a short assessment about acquired and inherited traits.

Observation 3.

The focus of the third observed lesson was on the characteristics of light, specifically how white light can be split into different colors, and the daily objective displayed on the board stated: “I can understand that white light is made of different colors.” The lesson began with Ashley asking her students what they already felt they knew about light, in particular about the color and light and their knowledge of how rainbows form (“Does anyone know what color light is?”; “When you hear the word spectrum, what do you think that they’re talking about?”). Ashley followed up these questions with additional questions about what they students may have already known about the terms light, color, and spectrum.

Following the questions, Ashley directed the students to get their laptop computers out and pull up a short informational passage about rainbows, prisms, and Sir Isaac Newton’s role in identifying the visible spectrum. Students read along as Ashley read the passage aloud for the class. After the reading, Ashley explained to the class that the lesson that day would be an exploration about how white light is composed of all of the colors of the visible spectrum as an introduction to their forthcoming unit on light and color. She then described the first part of their exploration using flashlights and plastic color filters. Students were given a worksheet with directions and a place for them to respond to prompts following each set of instructions. Students were organized into groups of three to four and were given three flashlights and three plastic color filters: red, green, and blue, after which Ashley turned out the light in the room. Following the directions, students used the filters to change the color of the white light from the flashlight and described on their worksheets how the filter changed the color of the light. They then overlapped the filtered colors from different flashlights and wrote down their observations of the resulting colors. Throughout this activity, Ashley moved from group to group providing performance feedback (“When you are dealing with light it’s not like dealing with paints.”; “You are to be using the vocabulary that you’ve been using today.”; “If you feel that you need to illustrate that, you can.”). Turning the lights back on, Ashley drew this first activity to a close by describing to the students what she had wanted them to be able to see when they overlapped each different color in different combinations. Although many of the students had a more difficult time producing the results Ashley had anticipated, they were heavily engaged in using the filters in a trial and error manner to produce different results.

After the first activity, Ashley collected the filters and distributed prisms. She instructed the students to examine and “explore” the prisms, with many students using the prisms like an eyepiece. Many students noted how when doing this, they could see different colors around different objects and people in the room, especially when they looked at the lights through the prisms. Afterwards, Ashley turned out the lights and instructed the students to use their flashlights to attempt to produce a rainbow with their prisms. When it became evident to Ashley that most of her students were struggling to project a rainbow, Ashley used a larger prism and an overhead projector to project a large rainbow on the front wall of the classroom. She then instructed the students to sketch the light that was projected through the larger prism. Like the first part of the lesson, Ashley moved around the room, interacting with each group, asking questions, and providing performance feedback.

Ashley drew this lesson to a close by giving her students two questions to respond to related to the activities: “Where do the colors of the rainbow come from?” and “Imagine you lived in a place where it never rains. How could you see a rainbow?” Ashley reminded the students while they are working on these questions that this lesson was an exploration that served as an introduction to the unit on light and color that they would be going into greater detail on later. She also posted a sheet of chart paper where several students began to write down their curiosity questions about light and rainbows. The following questions were posted by the students that afternoon: “Why do rainbows color in the same order?”, “Do the rainbows have to be in order?”, and “Why do we have a rainbow?”.

Participant 2: Descriptions of Observed Lessons.

During the study, three of Miranda's science lessons were observed. All three lessons occurred during what was the 3rd nine-week quarter of the school year at Normandy Elementary School.

Observation 1.

The focus of the first observed lesson was on life cycles of different organisms, specifically the life cycle of humans, and the learning goal displayed on the board stated: "I can compare the human life cycle to that of other animals." The lesson began with Miranda reviewing the work the students had done previously on the life cycle of a plant and informing them that the goal was for them to "develop and use models to compare stages of growth and development in various animals." Students then worked in collaborative groups to compare their own human life cycle models that they had been assigned to complete during a previous lesson. While the students were engaged in their collaborative work, Miranda checked in with each group, listening to student discussions, and asking clarifying or probing questions ("So what are some things you guys are noticing?"; "Where did you all start?"; "What did you notice that's different?") and providing performance feedback ("So [Student] added some milestones she knows humans have"; "So she noticed that in everybody's, they're all growing and getting bigger."; "So some people may have more stages than others.").

Miranda brought these discussions to a close and asked the students from each group to share out some of the things they noticed their different models all had in common from their discussions. Afterwards, Miranda displayed a blank life cycle with five stages on the interactive white board and asked the students to decide based on their

own work and discussions what they think the five stages should be in order to come up with a class-agreed upon human life cycle model. From this discussion, Miranda led the class in developing a single, agreed-upon human life cycle model.

Miranda then displayed pictures of three Caucasian babies on the interactive whiteboard and asked students in their discussion groups to describe what they observed about the three babies in terms of what characteristics the babies had in common and what differences they could see. While the groups engaged in their discussions, Miranda moved between student groups, listening to what students were discussing and providing direction (“Talk about what makes them similar.”). After their discussions, Miranda directed student attention back to the board and asked each group to share what they observed from the pictures (“What is similar about these three infants?”; “What are some things that are different?”). After the students shared what they thought the babies have in common, Miranda revealed that these were pictures of herself and her two sisters at the same age. She then showed them a picture of her at the age of her students (10 years). She asked students to discuss in their groups and predict which one of the baby pictures they thought was her, explaining that they needed to have evidence to back up the claim they were ultimately going to make. As before, Miranda moved between student groups at tables, listening to what students were discussing, asking questions (“So what do y’all think?”; “What about my nose?”) and providing performance feedback (“So she’s looking at those and she says the think’s it’s the one with the pink because of the nose.”).

Miranda brought the small group discussions to a close and asked each group to communicate their predictions and supporting evidence. The class came to consensus on their prediction and was validated when Miranda identified herself in the pictures.

Miranda transitioned to an activity about animal life cycles, using examples from the board and asking the students to describe the similarities they noticed between parent and offspring animal pictures on the interactive board. Student groups were then given a sample animal life cycle and were directed to compare that life cycle with the human life cycle. They were told that they will be sharing out their group's comparison in class the following day. Once again, Miranda moved between student groups at tables, listening to what students were discussing, asking questions ("Remember we are talking about life cycles. What are you comparing?") and providing performance feedback ("Stay focused. I think [Student] has a good point."). Miranda drew the lesson to a close and informed the students that they would finish their comparison work on the following day.

Observation 2.

The focus of the second observed lesson was on plant and animal characteristics, specifically the distinction between inherited and acquired characteristics and behaviors. The lesson began with Miranda reviewing the previous day's discussion about physical and behavioral characteristics as well as what they had discussed about the differences between inherited and acquired traits. During the review, Miranda asked questions to activate prior knowledge from the day before ("They have physical characteristics. What does that mean?"; "What you can see where?"; "What does it mean for a trait to be an inherited trait?"; "So what is an acquired trait?").

Following the discussion, Miranda explained the activity they would be doing for much of the lesson that day. Students would be working in small groups of three to four and rotating through six different stations. At each station, there was a description of an organism with several observed characteristics listed, some of which were physical

characteristics and some of which were behavioral characteristics. At each station, students worked collaboratively to respond to a prompt asking them to identify one or more characteristics as either inherited or acquired. Students were told that they needed not only to determine the nature of the characteristics, but also to support their claim with reasoning backed up by their prior knowledge from their previous discussion as well as the evidence from the details provided at each station. Groups worked at each station for approximately four to five minutes before being directed to rotate to the next station. As the groups worked, Miranda moved between student groups at tables, listening to what students were discussing, asking questions (“So what is an instinct?”; “Does the size of your foot change with the interactions with your environment?”; “Which one was something that was not something this plant was born with? And tell me why.”; “So would that be learned behavior or instinct?”) and providing performance feedback (“I’m not saying you’re right or wrong but I want you to think about it.”; “Write it down and tell me why you think that’s the right answer.”; “I want you to explain your answer to me.”). This was particularly necessary as many students displayed misconceptions about the nature of acquired versus inherited traits.

Miranda drew the lesson to a close by calling the groups back to their seats. She then posted two reflection questions on the interactive whiteboard: “What is the difference between an inherited trait and an acquired trait?” and “What is the difference between an inherited behavior (instinct) and a learned behavior?” Miranda directed her students to work on responding to the questions in their notebooks. As before, Miranda moved between student groups at tables, listening to what students were discussing, asking questions and providing performance feedback.

Observation 3.

The focus of the third observed lesson was on animal adaptations and survival, specifically animal mimicry, and the learning goal displayed on the board stated: “I can explain how animals use their adaptations to survive in their environments.” The lesson began with Miranda asking questions to activate prior knowledge from the previous lesson about adaptations (“So who can remind me what an adaptation is? In your own words.”; “What is a behavior?”). She then explained to her class that during the lesson that day they were going to be modeling the behavior of predators. During the activity, students were going to be modeling the role of predators in a simulation of mimicry using different beverages (lemon-lime soda, club soda, and fruit punch soda). Students were not informed at the beginning of the lesson that this was a simulation of mimicry, only that they were doing an activity related to animal adaptations.

Miranda described only what she wanted her students to do at each phase of the activity, not what she wanted them to understand. Initially, students were given two small cups of liquid (lemon-lime soda and club soda) and were asked to make observations using all of their senses except taste. She then asked members of the class to share out some of their observations. One of the main things that the students observed is that without tasting the liquid, they could not really tell them apart. Miranda explained that as predators, they were next going to consume their prey: a pair of butterflies represented by Cups A (lemon-lime soda) and B (club soda). After drinking from each cup, she asked them to write down their observations and then asked members of the class to share some of their observations. Student reactions to Cup A were positive and to Cup B were negative.

Miranda then gave the class the option of picking one of two more cups, Cups C and D. Cup D contained red fruit soda and Cup C contained a clear sparkling liquid (club soda). She showed the students the two cups and asked them to make a choice as this time they are only going to get to drink one of them. Most of the class selected Cup D, with only a few selecting Cup C. After the students made their choices and consumed their liquids, she interacted with some students, asking them about their choices and reasoning. Most of the students concluded that if they were a predator, they would go after the butterfly represented by Cup D because that was distinct from Cup C or B.

Miranda transitioned the activity to explain the how the simulation was an example of the mimicry adaptation. This was followed with several examples Miranda showed and read about from the interactive whiteboard: Viceroy Butterfly versus Monarch Butterfly, a fly that looks like a hornet, King Snake versus Coral Snake, Stick Bug, and a moth with owl eye patterns on wings. With each example, the class discussed how it was an example of mimicry and how that helped the animal survive. Miranda drew the science lesson to a close by directing the students to get their laptops out and respond to the following prompt: “How can mimicry help an organism survive in their environment?”

Participant 3: Descriptions of Observed Lessons.

During the study, three of Tali’s science lessons were observed. Two of the lessons occurred during what was the 3rd nine-week quarter of the school year with the final lesson taking place during the beginning of the 4th nine-week quarter at Grissom Elementary School.

Observation 1.

The focus of the first observed lesson was on the characteristics of organisms, specifically being able to determine physical characteristics that are inherited, and the learning goal displayed on the board stated: “I can explain life cycles of plants and animals.” The lesson began with Tali reviewing what the students had already worked on during their organisms unit, specifically life cycles of plants and animals and classifications. She then explained that they are going to be focusing on inherited characteristics using a video from a curriculum with which the students were familiar.

Before she started the video, she led a class discussion on the science performance indicator they were attempting to address in this class: “Construct scientific arguments to support claims that some characteristics are inherited from their parents and some are influenced by the environment.” Students discussed what they think they will be doing in terms of a scientific argument and using evidence to support claims. She then showed them a question from the curriculum: “How could you grow your own sweet apples?” After the students wrote the question down, she started the video.

The video presented information about the nature of inherited characteristics as well as a scenario about how selecting seeds from sweet apples and replanting only those seeds, it would be possible to produce very sweet apples. Throughout the video, Tali stopped the video and asked the students questions about both their learning goal and what they were watching (“What does construct scientific argument mean?”; “What makes you guys think you can just take the seeds out of an apple and plant it?”). At one point, she showed a picture of her family, including her sisters, and asked the class what physical characteristics they noticed different family members had in common (“What

are some of the differences you can tell between me and my two sisters?"; "Do you think that was inherited from our parents?"). Her students showed familiarity with her sister, asking if they were looking at one they had heard about before.

After the video, Tali explained that each student was going to get samples of four different apples. The students tasted each apple and assigned a numerical value to the sample based on how sweet they thought it was, similar to how this was done in the video. Students then made bar graphs illustrating their data. Tali ended the class by explaining that for homework she wanted them to identify a trait they had in common with one of their parents or another family member and to be ready to identify this trait, describe which family member they had it in common with, and support their claim with reasoning and evidence.

Observation 2.

The focus of the second observed lesson was on plant and animal adaptations and the learning goal displayed on the board stated: "Adaptations of Plants and Animals" The lesson began with Tali going to each student and taping the thumb of each student's writing hand down, explaining that they would have a chance to explain to her why she did that by the end of class. She then began activating prior knowledge by asking her students about adaptations ("So tell me what did we come up for a definition for what adaptations are?"; "Who can tell me another adaptation we learned from yesterday?"). After the students recounted the definitions they developed as a class, Tali instructed the students to bring out a sheet they had begun working on the day prior and to work collaboratively in groups to figure out what physical and behavioral adaptations are. While this was taking place, Tali moved around the room, checking on the progress of

each group and asking probing and clarifying questions (“Alright, did y’all figure out how they’re different?”; “So what are some connections to our words?”). After several minutes, Tali directed their attention back to her and asked for different students to share out what they figured out based on their discussions.

Next, Tali began to explain the four rotation activities in which they would be participating. Throughout most of the remainder of the lesson, the students spent approximately 10 minutes at each location before rotating to the next station until all of the students had engaged in all four stations. The four stations included:

- Bird’s Beaks- each group was given a soil sample containing gummy worms, a tray of rice containing dried peas, and a container of water containing cereal. The group tested four different methods of bird-beak adaptations using tongs, water droppers, clothespins, and spoons on each source of food and determined which one was the most effective means of getting different types of food based on the shape and nature of the beak.
- Plant Adaptations- students worked independently using their laptops to research information to complete their work from the previous day on what kinds of adaptations plants would need for different habitats and ecosystems.
- Animal Movement- students mimicked different animal movement styles (hummingbirds, snails, grasshoppers, and a cheetah) and then discussed their thoughts on what they think the advantages and disadvantages of each adaptation might be. On this day, Tali had a student teacher present helping with this station.
- Mimicry- students engaged in the mimicry simulation whereby they tasted different cups of identical-looking liquids (lemon-lime soda and carbonated

water) and then decided whether they wanted to taste from cups of liquids that appeared different (cola and carbonated water) based on their initial experience with the first two cups. This was followed by some reading and discussion of different examples of animal mimicry and what the students figured out about how this adaptation works and why. This activity was very similar to the activity in Miranda's third observed lesson.

During the rotations, Tali moved around the room, checking on the progress of each group, asking probing and clarifying questions ("What do you see in that cup?"; "So what do you think that adaptation is?"; "So what are you already conditioned to pick? Why?") and providing performance feedback ("And after that you will tell me why that's the best beak for each one."; "I don't want to know what the environment looks like. I want to know what the plant needs to survive in that environment.").

Following all four rotations, Tali brought the class' attention back to her and asked for volunteers to share something they learned from each of the four stations. Tali then ended the science lesson by informing the class that on their field study the next day they would get a chance to look for additional plant and animal adaptation at a local national park.

Observation 3.

The focus of the third observed lesson was on the way light interacts with different materials, specifically reflection, refraction, absorption, and transmission. The learning goal displayed on the board stated: "I can describe how light travels and interacts when it strikes an object." The lesson began with Tali asking students questions about a previous lesson to activate prior knowledge related to using a prism to split white light

into different colors (“We looked at all the different colors in the dark and we realized that the light is actually what helps us do what?”; “We realized that light was made of what color?”; “Who remembers how we said we can remember those colors?”). Students related what they had learned about light, including how light was necessary for visibility. Tali then used an overhead projector to project the light through a prism and asked students what they remember about refraction with regard to the prism splitting white light into different colors. Tali then arranged her class into groups of two to four students and directed them to copy their learning goal into their notebooks and to read about the terms reflection, refraction, and absorption from pages in their textbook. They then worked in their groups to come up with their own student-language definitions for those words.

As this work was group-paced, Tali informed her students that once they were done with their work, they were to get her attention so she could check on their student-generated definitions. Afterwards, each group received a basket of materials and began to follow the directions on a series of short observations into different phenomena for how light interacts with different materials. For each phenomenon, students were to write their observations, draw a picture of the phenomenon, and determine if it was an example of transmission, reflection, refraction, or absorption. She also explained that they would not get through all of their activities that day as they needed to leave early to attend an author’s study. Phenomena observed during the lesson include the following:

- Shining a light at a prism
- Dropping a marker into a clear cup of water
- Observing a reflected image on a pair of sunglasses

- Observing an image of an arrow through a clear cup of water
- Observing letters through a magnifying glass

Students started their work, first on their definitions, then on their group based observations. Throughout this work, Tali moved from group to group, checking on progress, asking guided questions (“Light bounces off of it. So what happened? What do you think that means?”; “So what does that mean that it’s absorbed?”; “Does it shine through?”; “So does refraction only work with a prism?”) and providing performance feedback (“Oh, good question.”; “I like that one.”; “Elaborate a little more.”; “So it looks like its bent. So that does go with that vocabulary work.”). Tali ended the science lesson by asking the students to put their three definitions into their own words in order to begin the process of crafting a class-accepted definition for reflection, refraction, and absorption.

ANALYSIS OF SCIENCE-RICH PHYSICAL ENVIRONMENTS

During the observations, many of the characteristics of the teachers’ classrooms illustrated how the physical settings were intentionally designed to support both a science-rich learning environment and a social constructivist setting in which students are encouraged and expected to work collaboratively in a manner that supports group work and discussion.

All three participants arranged the seating in their respective rooms so that students could sit in groups. In Ashley’s classroom, student desks were arranged in groups of two or four depending on the needs of the lesson. Chairs were arranged so that students could face one another or turn to face the front of the classroom as needed.

There was also an open space in front of the classroom’s interactive white board where

students could sit either as a whole class or in small groups depending on the nature of the lesson. On one side of the room, there was a semi-circle table that Ashley sometimes allowed students to use when she needed to create more small groups than she had space for with her typical configuration of desks, as was the case in the second observation. Miranda also arranged her classroom so that students could sit in groups, typically of two to four students at desks arranged in pairs or clusters. At the front of the room, in front of an interactive whiteboard, the cluster of four desks were low to the ground, with the students sitting on the floor when engaged in class work. Although most of the students sat at desks, these desks were arranged in groups of two or four depending on the needs of the lesson. Chairs were arranged so that students could face one another or turn to face the front of the classroom as needed. At one cluster of desks, four regular chairs had been replaced with large bouncy balls for students to sit upon. On one side of the room, there was a sitting area with a small sofa where students were permitted to work in pairs or independently depending on the nature of the lesson. Similarly, there was a rocking chair near the entrance of the room in an area where students were also permitted to work as appropriate to the lesson. In her classroom, Tali also arranged the desks so that her students could work in groups. The desks were clustered in groups of two to six depending on the needs of lesson. There was also a small table in the back of the room where a pair of students can sit. Tali sometimes used this table to stage materials depending on the needs of the science lessons. In the center of the room, there was a small sofa with a low table in front of it. Students could sit here for small group collaborative work as well. There was a large open space in front of the interactive whiteboard at the front of the classroom. During the second lesson, this space was used as

one of the stations during rotations. In one corner of the room there was a pair of chairs adjacent to a class library.

The layout of these classrooms provides the teachers with the flexibility to shift the learning from whole-class direct instruction to small group collaborative work, including being able to set up different tasks at stations around the rooms. Furthermore, Miranda and Tali also demonstrate flexibility in meeting the needs of their students as they work both collaboratively and independently as illustrated by the presences of the different seating areas beyond the desk-clusters. In the case of Miranda’s classroom, this flexibility and the desire to meet students’ needs is further illustrated by how she uses the bouncy-ball seats at some of the desk-groups. In particular, Miranda described how the seating arrangement in her classroom was an intentional effort to “create a space that is comfortable and conducive to student engagement,” while at the same time meeting the needs of what she described as the different learning styles of her students.

In all three classrooms, there were several features that illustrate how these teachers created a science-rich learning environment for their students. For example, all of the teachers displayed science learning goals as part of the daily agenda written on the dry erase board at the front of the room. Typically, these goals were written in student-friendly “I can...” statements. For example, in Tali’s room, one of the goals that was on the board during an observed lesson was “I can describe how light travels and interacts when it strikes an object.” Similarly, Miranda displayed student-friendly learning goals, such as “I can explain how animals use their adaptations to survive in their environments.” In Ashley’s case, the goals were written as “I can understand...” statements, such as “I can understand inherited traits and learned behavior of organisms.”

Also, in Ashley’s room, there was a daily timeline for the class that illustrated for her students that science was typically taught between 1:20 and 2:30 daily, suggesting that Ashley routinely plans for at least 60 minutes of science instruction daily. Not only do these goals communicate the content and, to some degree, expectations of the level of understanding and performance the students are expected to engage in, these learning goals were aligned with relevant performance indicators from the state’s science standards.

Additional evidence of the way the teachers created a science rich learning environment comes from various science artifacts prominently displayed around the room. All three teachers had various live material specimens in their respective rooms, indicating that these were part of on-going life-science investigations. For example, Ashley had two live plants that were part of the class’s plant observation data collection and Miranda had a collection of containers with soil and water samples in them that served as study habitats for their ongoing organisms unit. Tali’s room had the most diverse collection of live materials stations, including several small cups under a grow light with plants sprouting from them, a collection of small plastic cups containing mealworms and pieces of fruit, and a pair of plants growing in small hydroponic containers in the front of the room. All three classes also had classroom libraries that included collections of non-fiction science books. In the case of Miranda’s libraries, there were baskets specifically labeled “Animals and Their Environments” and “Weather and Astronomy.”

On the walls of Miranda’s and Tali’s classrooms, there were also science-related materials on display. In Miranda’s room, these included a subject-specific word wall with

science-specific vocabulary, chart paper with information about various past and present science content the classes were studying, and student drawings of human life cycle models. All the chart paper artifacts were teacher created and were not publisher produced. Similarly, on the walls of Tali's room, there were also several science related artifacts posted throughout the room. These included a piece of chart paper with weather-related topics written out on it, as well as several publisher-acquired mini-posters depicting definitions of qualitative and quantitative observations, visual models of weather phenomena, and visual models of related to astronomy. On several large sheets of colored paper, there were many small cut-out pictures of different animals arranged and classified based on different characteristics. While Ashley's classroom lacked the presence of science artifacts on the wall, she did eventually display the completed KLEWS (Know, Learning, Evidence, Wonder, Science Vocabulary) chart that the class initiated as part of their initial brainstorming during the first observed lesson on the characteristics of plant seeds.

ANALYSIS OF OBSERVED SCIENCE PRACTICES

Ashley, Miranda and Tali each employed a variety of different techniques and practices that reflect many of the defining characteristics of an inquiry-driven approach to teaching science, including elements that reflect a social constructivist approach to learning.

Congruence of instructional goals with state standards.

The focus of the lessons and their alignment with the instructional goals of the state's science standards and performance indicators indicate an understanding of the nature of the both the science concepts underlying the standards as well as the

performance expectations of the embedded science and engineering practices. For example, in Ashley’s lesson on inherited and acquired characteristics, her students engaged in the process of supporting their claims regarding the characteristics of organisms through reasoning. Ashley’s students worked through different stations, focusing on how certain traits can be recognized as inherited based on physical characteristics of plants as well as distinguishing between acquired and inherited traits and behaviors. In all but one of these stations, students worked collaboratively, engaged in discussions to explain their reasoning not only to one another but also to Ashley. This focus on reasoning is an element of the SEP “engaging in arguments from evidence” (NRC 2012) and is congruent with the state’s performance indicator “Construct scientific arguments to support claims that some characteristics of organisms are inherited from parents and some are influenced by the environment” (SCDE, 2014).

Miranda’s lesson on the human life cycle illustrates congruence not only with the state’s performance indicator “Develop and use models to compare the stages of growth and development in various animals” (SCDE, 2014), but also with the SEP “developing and using models” (NRC, 2012). In this lesson, her students were tasked with developing models that represent the human life cycle. They then examined the life cycles of other animals and began collaboratively engaging in a comparison before the class ended. In the lesson on animal adaptation, Tali’s students engaged in various simulations of animal adaptations that enabled them to support their explanations for how these adaptations would help the organisms survive. This is highly congruent to the performance indicator “Construct explanations for how structural adaptations (such as methods of defense, locomotion, obtaining resources, or camouflage) allow animals to survive in the

environment” (SCDE, 2014) as well as the SEP “constructing explanations and designing solutions (NRC, 2012).

Use of authentic science and engineering practices.

It is also significant that the students of the three teachers frequently engaged in authentic science and engineering practices (SEPs) congruent with these performance indicators.

Analyzing and interpreting data.

Collecting and analyzing observational data plays a key role in lessons observed for all three teachers. When investigating the shape of different seeds, Ashley directed students to engage in the process of observing. “Look at the shape of it... Yeah it does have the appearance of an onion.” Ashley’s students frequently shared their observations with one another, as well as with the entire class, such as when they were describing the shape and appearance of different seeds; “They have different shapes and sizes”; “When you look at the lima bean it looks like a clam shell.” Observation also played a role in Ashley’s lesson on white light. Early in the lesson, Ashley communicated to her students that the purpose of the learning was to begin an exploration into the nature of white light and color. She put the focus on students collecting data through observations, writing down and illustrating what they see, as a precursor to understanding.

In Miranda’s lessons, students also engaged in the practice of collecting and using observational data to support claims and explanations. In the lesson on developing models of the human life cycle, Miranda instructed her students to “take a look at these three baby pictures... I want you to think about what characteristics do these infants...do these infants all have in common? What things do they have that are similar and what

things do they have that are just a little bit different.” In this example, Miranda expected her students to engage in observations and to use those observations as the basis for their comparison and, later, to support their claims regarding which baby is her. In the mimicry lesson, observations once again played a role as she required students to record their observational data regarding the different liquids. Miranda then drew these observations out of her students through her questions about which butterfly analogue they would eat. Similarly, in Tali’s lesson on adaptations, she, too, engaged her students in collecting observation data through their simulations of animal movement, bird beaks, and mimicry, all with the purpose of using those observation to help them construct an understanding for how a given adaptation helps an organism survive. Tali’s students also collected observational data in the lessons on inherited traits, when they conducted observations of different types of apples, as well as when they observed the different ways light behaved through reflection, refraction, absorption, and transmission.

Not only is the collection and analysis of data through observations an integral part of the learning in these examples, it is also congruent with the SEP “analyzing and interpreting data” (NRC, 2012) and is congruent with practices either explicitly defined by the performance indicator or implicitly embedded in the processes.

Engaging in arguments from evidence.

Throughout these lessons, Ashley, Miranda, and Tali’s students frequently engaged in using evidence, both from collected observations as well as from scenarios and simulations, to support claims with reasoning. This use of evidence and reasoning to support claims being made about phenomena the students were observing is a characteristic of the SEP “engaging in arguments from evidence” (NRC; 2012).

In the following exchange, Ashley asked her students to describe how and why they associated different types of fruit based on the appearance of the fruits' interiors.

Ashley: "Who did the plum and the cherry? Why did you choose the plum and the cherry?"

Student A: "Because of color."

Ashley: "That's fine. So, either way, that's however you saw that and you can back that up with evidence."

Ashley: "So the inside of this plum, the inside of this cherry, the inside of this grape. Which two did you say are related?"

Student B: "The plum and the cherry."

Ashley: "Why"

Student B: "Because they both stone fruit. Because they only have one seed and they are both stone fruit."

Ashley: "But did the grape have the pit?"

Students: "No"

Ashley: "No, it had that small seeds... That's one trait."

In this exchange, Ashley did not tell her students whether their classification is accurate. She explicitly stated that what is important is that they can "back that up with evidence." While the evidence was not generated by the students in this lesson, having been provided by the teacher through the use of illustrations, photographs, and scenario descriptions, nevertheless, the students were using that evidence and applying reasoning to support their claims regarding the nature of these characteristics.

Similarly, in two of Miranda’s lessons, reasoning from evidence played a role in the work in which the students were expected to engage. For example, when making the case for which infant picture was her in the first lesson, Miranda instructed her students to “look at the facial characteristics that they have and see which one you think is me. Talk with your group. You’ve got to give me evidence to back it up.” In the lesson about inherited and acquired traits, students were expected to work collaboratively to not only determine which of the described traits are acquired or inherited depending on the prompt; they were also expected to support those claims with reasoning. In the following exchange, Miranda used her questions to elicit the reasoning from her students regarding a dog’s behavior.

Miranda: “Which one is most likely an instinct, something the dog did not have to be taught?”

Student: “Uhhh this one because when she holds up the treat, she knows it’s for her.”

Miranda: “Why do you know it’s not number 4?”

Student: “Because when it’s hot outside, every dog sometimes pants.”

Miranda: “So you’re saying every dog pants? Do you have to teach a dog to pant?”

Student: “No?”

Miranda: “So would that be a learned behavior or an instinct?”

Student: “An instinct.”

In Tali’s lesson on inherited characteristics, Tali made a point of communicating the exact nature of the state’s learning goal, “Construct scientific arguments to support

claims that some characteristics of organisms are inherited from parents and some are influenced by the environment,” to her class when she posted the performance indicator on her board. Although the lesson itself did not reach the level of students supporting claims, throughout the lesson, Tali focused on the background information necessary for her students to be able to support their claims in the future with both evidence and reasoning. In this case, the reasoning would occur by connecting the foundational learning that took place in this lesson with additional evidence collecting in subsequent lessons.

In all three teachers’ cases, students were expected to engage in reasoning, using evidence either collected through observations and simulations, or provided by the teachers, to support claims. While the students do not engage fully in the practice of engaging in arguments from evidence, the process of supporting reasoning with evidence is one element of this SEP (NRC, 2012).

Constructing explanations.

Student also engaged in constructing explanations throughout the lessons. During her lesson on white light, Ashley’s students were expected to use their observations of the behavior of white light as it interacts with color filters and prisms to construct explanations for how light is composed of different colors. Miranda’s students engaged in the practice of constructing an explanation when they used their experiences with the mimicry simulation to describe how this particular adaptation would help a prey animal survive. This is not only highly congruent to the performance indicator “Construct explanations for how structural adaptations (such as methods of defense, locomotion, obtaining resources, or camouflage) allow animals to survive in the environment”

(SCDE, 2014), it also aligns with the SEP “constructing explanations.” (NRC, 2012) Similarly, in her lesson on adaptations and survival, Tali’s use of the various stations where students worked through different activities focusing on simulating different animal adaptations was also congruent with the same performance indicator and SEP in that her students were tasked with not only describing what was happening in the simulations, but also making connections between the outcomes of the adaptation simulations and the broader concept of survival by constructing explanations for how the adaptations are beneficial to an animal’s survival.

Develop and using models.

Although Ashley did not employ the SEP “developing and using models” (NRC, 2012) during any of the observed lessons, both Miranda and Tali did. In the lesson about life cycles, Miranda’s students were tasked with developing models that represent the human life cycle. They then examined the life cycles of other animals and began collaboratively engaging in a comparison before the class ended. Not only does this align with the state’s performance indicator “Develop and use models to compare the stages of growth and development of various animals” (SCDE, 2014), Miranda’s students worked through the process of developing their own models, one of the NRC *Framework’s* SEPs (NRC, 2012). Modeling also played a role in Miranda’s third observed lesson, although this time the students were not developing a model; rather, they used a model, in this case the mimicry simulation, as an interactive experience to support their explanations for mimicry and survival. Tali’s lesson on adaptations was similar in many respects to Miranda’s, although she employed multiple examples learning adaptation through simulations, including a similar simulation of mimicry, a simulation of bird beaks, and a

simulation of animal movement. In all three cases, Tali’s students used the models, represented by the different simulations, as sources of information and experience to help construct their explanations for how different adaptations help animals survive. Both the act of developing models as well as using models to experience different phenomena are congruent with the SEP “developing and using models” (NRC, 2012).

Finally, in the lesson where students were investigating different phenomena related to interactions with light, while the students did not engage in the practice of developing and using models, defined by the congruent performance indicators as “Develop and use models to describe how light travels and interacts when it strike and object (including reflection, refraction, and absorption) using evidence from observations” (SCDE, 2014), they did engage in investigations of these different phenomena in order to collect data and classify the nature of the interaction, both of which are essential steps towards being able to develop and use models.

Obtaining and communicating information.

Obtaining, evaluating, and communicating information was one of the SEPs that is found embedded throughout all of the observed lessons. In Ashley’s lessons, her students obtained information in the form of data collected through observations (the seed activity and the white light observations) and from the different scenarios, photographs, and illustrations they would use to support their claims regarding inherited and acquired traits. During the lesson on life cycles, Miranda’s students obtained information from the observations of photographs and in the lesson on mimicry from the specimens provided during the simulation. Her students also obtained information during the lesson on acquired and inherited traits from the different scenarios they used to construct their

reasoning. Finally, Tali's students similarly collected information from observations during all three lessons.

Communicating information was another element of the SEP that implicitly occurred throughout every lessons. In most cases, this was done through their whole class discussions during which the teachers would prompt the students with questions designed to elicit evidence of reasoning and understanding from them. What makes obtaining and communicating information a relevant SEP is when it is engaged in with the intentionality of obtaining information for a specific purpose as opposed to for the sake of merely memorizing scientific facts. It is also an appropriate use of this SEP when the act of communicating that information is similarly tied to a relevant purpose, such as constructing an explanation or supporting a claim with reasoning (NRC, 2012).

Differences among participants' use of SEPs.

Although Ashley, Miranda, and Tali all engaged their students in the use of SEPs, there are some notable differences between the three teachers. Ashley's students largely engaged in collecting and organizing data, as evidenced in her lessons about seeds and the nature of white light. Additionally, during the lesson on acquired and inherited characteristics, her students engaged in the practice of supporting reasoning with evidence, largely acquired through pictures and scenarios provided by the teacher at each station. Ashley's students also engaged in sense-making conversations that involved a process of constructing explanations, most evident in the lesson about acquired and inherited traits.

Miranda's students also engaged in the practices of constructing explanations, though unlike Ashley, her students supported their explanations through evidence and

their experiences from the mimicry simulation. Collecting observational data also played a different role in her class as it was tied to the mimicry lesson and was part of the simulation experience. Unlike Ashley, Miranda also engaged her students through the process of developing and using models when they created their own human life cycle diagrams and compared them with one another in class to develop a single class-developed life cycle model. Miranda's students also engaged in the use of models through the simulation in the mimicry lesson. In this lesson, the simulation served as a model for a real-life phenomenon from which her students could collect data and use to support their explanations following the simulation.

Of the three teachers, Tali's students engaged in the practice of directly collecting observational data more often than the other two classes. Tali's students collected data from the apple specimens during the lesson on inherited traits, from the different simulations during the adaptations lesson, and from the different light interactions during the light lesson. Tali's students also engaged in the practice of constructing explanations during all three observed lessons, though the nature of their work varied depending on the lesson. During the lesson on inherited traits, her students constructed their explanations based on teacher prompted questions and supported them using information provided by the video. In the second lesson, the students primarily used their experiences with the different adaptation simulations to construct their explanations and during the light lesson, they used their observations of the different phenomena. While Tali's students also engaged in the practice of supporting claims with evidence, this practice was more closely tied to their work with constructing explanations using their experiences and evidence.

Sequencing of learning experiences.

Several times throughout the observed lessons, the manner in which the teachers implemented their science lessons was congruent with an inquiry approach to teaching science where students would first engage in the phenomenon they were learning about through observations or simulations and then use their observations, experiences, and prior knowledge to attempt to make sense of that phenomenon in the context of broader science conceptual understandings. For example, in Ashley's lesson on light, prior to any direct instruction on the nature of white light, in communicating the purpose of the introductory lesson, she explained, "What we are going to do is we are going to explore a little bit." Even though the students read from a short text about white light prior to their observations, the teacher took no actions to help students understand the reading or provide direct instruction to explain the concepts covered in the reading. Instead, students launched directly into the observations with the intent of witnessing two different phenomena related to white light followed by discussions that focused on what they thought was happening during their experiences with light. In Miranda's lesson about adaptations, she used the mimicry simulation as a way for the students to experience the phenomenon in order to begin the process of constructing an explanation for how it helps an animal survive before providing them with a more formal definition and set of examples for mimicry. Similarly, while students had some basic prior knowledge of what adaptations were based on prior learning experiences, the simulation itself served as the initial exposure to the mimicry phenomenon. This was followed by discussions about what the students thought were the advantages of mimicry and then additional examples of mimicry, presented through direct instruction. Even during the direct instruction, the

focus of the learning was through discussions prompted by Miranda's use of questions to probe student ideas. When Tali's students investigated how light interacts with different materials, although they first looked up terms in the textbook, Tali did not provide any direct instruction or supporting explanations for what they were reading. Instead, Tali wanted her students to take the basic definitions and work collaboratively to unpack the meaning of those terms and concepts in a way that made sense to them. The subsequent investigations into the different phenomena served the purpose not only of helping them recognize the occurrence of the phenomena they had defined in their words, but also of helping them further construct their understanding of the science concepts they had begun to articulate in their own way by being able to see the phenomena as real-world manifestations of these concepts. The purpose of the exposure to the textbook definitions at the start was not for students to memorize different science terms. By having her students work to articulate the terms in their own words as part of a collaborative effort, notably without direct instruction on the part of the teacher, the emphasis was on sense-making. This made the observations of different phenomena that followed an extension of that sense-making, not merely a verification of memorized facts.

In displaying overarching learning goals, as well as verbally relating that goal to their students, these teachers were communicating to their students what the target for their learning was on any given day. In this way, the learning goal does not serve the function of providing scientific knowledge for them to internalize. Rather, the three teachers expected their students to work, often guided by questions, on understanding what that goal meant in terms of the phenomenon they were studying, as well as providing reasoning and evidence to support their understanding of the phenomenon. In

effect, the learning goal was a target that the students did not fully understand at first but would come to make sense of through their explorations and investigations, facilitated by their teacher.

For example, at the beginning of her lessons the nature of white light, Ashley's use of questions to elicit student ideas about what they already know followed by putting their words on display on the board, made it clear that she was interested in their knowledge at the start of the learning process, not in providing scientifically accurate definitions and explanations of concepts.

Ashley: "How many of you agree with that, that light is white?" (a few hands come up) "Okay, how many of you don't agree with that?" (many more hands).

"Okay, we're going to explore that today."

Although she communicated the learning goal at the outset, "I can understand that white light is made of different colors," she intentionally did not start this lesson with a focus on the scientifically accurate explanation for this phenomenon. Instead, she accepted responses that showed misconceptions, choosing not to immediately address those misconceptions, but communicating that they, the students, would be the ones to construct an understanding of the learning goal during their explorations.

Teachers' use of questions and sense-making discussions.

Many of the strategies employed by the three teachers focused the learning experience on sense-making with the aim of developing understanding. In the observed lessons, this was often done using questions in a variety of ways to spur sense-making dialogue among their students working collaboratively in small groups.

All three teachers used questions at the start of the observed lessons as a way to elicit student ideas about the topics they were going to be learning about during each day's lesson. In some cases, this allowed students to activate prior knowledge if the questions were about topics that had been covered previously but were also related to what would be explored in class during the upcoming lesson. For example, in addressing her questions to the entire class, Miranda used her questions about characteristics and traits, such as, "What does it mean for a trait to be an inherited trait?" and "So what is an acquired trait?" to activate her students' prior knowledge in preparation for the lesson in which they would be supporting their reasoning with regard to whether a described characteristic or scenario was an example of an inherited or acquired trait. Similarly, Tali's questions to her entire class at the start of the adaptation simulations lesson were also used to activate prior knowledge from the previous lesson's content, such as, "Who can tell me another adaptation we learned from yesterday?" Ashley would use questions at the start of the learning experience to elicit ideas about topics that her students had not yet explored in great details. Instead of serving to activate knowledge from a previous lesson, questions such as "How do we want to define characteristics?" and "What do you think learned behaviors are?" served as a way to create anticipation in the upcoming lessons as well as a way by which Ashley could gauge to what degree her students might already have some ideas about the upcoming topic.

Another way the teachers used questions was to probe their students' ideas and understandings of the concepts they had been developing through the work of their current lessons. Ashley often used questions to probe her students' ideas about the experiences in which they had engaged. This often resulted in teacher-student discussions

whereby her student would be compelled to explain his or her reasoning, in effect, either constructing an explanation for the phenomenon the class was investigating or supporting decisions he or she was making in the lesson. Ashley would even go so far as to warn her students to expect this by reminding them “Y’all know I’m going to ask the ‘why’ question.” In recognizing inherited characteristics, she used her questions to not only probe the ideas of her students for how they classified different types of fruit based on their physical characteristics, but also to compel them to explain their reasoning, engaging them in the process of reasoning through their evidence to support their claims. Questions such as “Why can you tell that’s a pumpkin seed?” and “Are there any others that go with citrus? What do you see that is similar?” were used to probe evidence of student thinking and reasoning through discussion. In these cases, the focus was on the process as much as on the science concepts related to the parts of plants or the classification of a plant based on its characteristics. This is also evident when she used her questions to press her students to communicate not only what they figured out, but also their reasoning behind their response. In this exchange, Ashley uses one of the examples from the station where the students are to distinguish between acquired and inherited traits and behaviors.

Ashley: “A goldfish swims to the top when it sees someone’s hand over the bowl.”

Students: “Learning behavior”

Ashley: “Why?”

Student A: “A goldfish swims to the top is a learned behavior because we have pet goldfish and if you feed it, it knows that if it sees your hand it is going to get fed.”

In a similar manner, Miranda’s use of questions to probe student ideas about the phenomena fostered sense-making, collaborative discussions. In communicating her expectations to her students, Miranda made a point to explicitly foster collaborative discussion as the means by which they are expected to make sense of what they were learning about. For example, in the lesson about inherited and acquired traits, Miranda reminded her students “When you’re working with a group you don’t want to stay silent because you want to communicate and collaborate with each other. But it should be at an inside voice.” In her lesson on life cycles, Miranda intentionally built in time for her students to discuss with one another before sharing out their reasoning with the whole class. And in the lesson on organism characteristics, she expected her students to discuss their reasons for classifying a trait as either inherited or acquired.

Tali’s students were also frequently engaged in conversations about the phenomena they were studying, usually in an effort to make sense or come up with an explanation, such as when they reasoned with one another about which different bird beak analogue was best adapted for a certain food source or when they explained why they felt certain movement adaptations were an advantage for different animals. Tali’s use of questions to probe the evolving ideas of her students also fostered discussion during which they engaged in a process of sense-making to articulate their growing understanding in their own words.

In this exchange from the third lesson, Tali asked her students for their reasoning behind how they were classifying their observation of a marker seen through a clear cup of water.

Tali: (reading from a student observation) “The marker is displaced.’ What do you mean by displaced?”

Student A: “When we take it out it’s normal, but when we put it in, it looks really big and it looks shifted.”

Tali: “Ah, it looks shifted. What word do you think that connects with? Reflection, refraction, or...”

Student A: “Reflection because the water is reflecting...”

Student B: “Absorb.”

Tali: “Do you think it’s absorb? Absorb means its soaking something up.”

Student A: “Well the marker is absorbing some of the water.”

Tali: “You think it’s going right through it?”

Student C: “I think it’s refraction.”

Tali: “The marker looks broken.”

Student C: “No.”

Tali: “It doesn’t?”

Student A: “It does.”

While it may have been easier to simply demonstrate the phenomenon and then provide a detailed explanation for it, Tali used her questions to engage the students in a dialogue with the intention of not only probing their understanding, but also to challenge their thinking in order to guide them in the process of making sense of their observations.

Teacher as the facilitator of the learning experience.

Ashley, Miranda, and Tali all demonstrated a manner of teaching in which they assumed the role of the facilitator of learning as opposed to the knowledge authority in the classroom. When Ashley first began exploring a topic with her students, as well as when they are working in collaborative groups, she frequently asked students about their thoughts or ideas about the topic, seldom, if ever, affirming or correcting their ideas, especially at the earlier stages of the learning experience. In this exchange, when her students were sharing their ideas about behavioral and physical adaptations, she made sure to capture what they were saying rather than imposing what she felt was the accurate definition.

Ashley: “So how do you want me to write that?”

Student A: “A way for animals to survive in their habitat... A behavior that they learned based on failing from other types of behaviors.”

Student B: “An adaptation learned, based on their habitat, their family, and where they go.”

Ashley also illustrated that the process of learning science was not about getting it “right or wrong”; rather it is about going through the process of trying to figure it out. For example, during the second lesson, when Ashley asked her students what they already knew about inherited and acquired characteristics, she explained “When you’re brainstorming, it’s not about right or wrong. It’s just brainstorming because once you get to start learning through the teaching, you get a little bit more clear about what you’re talking about.” In this way, she deemphasized the importance of getting a correct answer, at least at this early stage of exploring the phenomenon; rather she placed the focus on

student knowledge and understanding, illustrating that knowledge construction is a continuously evolving process.

In a similar manner, Miranda did not assume the traditional role of the knowledge authority, in which her students recognize and rely on her as the source of information. Rather, through her use of probing questions and her focus on discussion and reasoning, Miranda was the facilitator and guide in the learning experience. For example, throughout all three observed lessons, Miranda frequently put the responsibility on her students to explain their reasoning as opposed to her giving them a scientifically accurate explanation. During the lesson about acquired and inherited traits, Miranda reminded a student of her role by stating “I’m not saying you’re right or wrong, but I want you to think about it.” In another example from this lesson, she directed a student to “Write it down and tell me why you think that’s the right answer.” In the third lesson, Miranda focused on student explanations for mimicry: “So we have looked at three examples. So why do you think animals mimic other animals? What’s the purpose? Why do they do it?” Furthermore, the nature of the simulation and the way Miranda guided her students through it without providing an explanation illustrates how she approaches science teaching as the provider of experiences from which students construct their knowledge.

Tali’s instructional style reflects elements of social constructivist science inquiry teaching in how she assumed the role of facilitator of learning through her use of questions designed to elicit discussion and explanation as well as through her focus on explanation through discussion as opposed to memorizing scientifically accurate information. For example, in the lesson on inherited traits, Tali used questions to give students an opportunity to figure out their own ideas and definitions when she asked them

“So inherited characteristics would be what? What is your definition of an inherited characteristic?” This exchange from that same lesson highlights how Tali asked her students to build upon what they learned from the video about apple trees, with different students sharing out their own ideas on how they could begin to develop apples trees that produce sweeter apples.

Tali: “Alright who wants to share your thoughts?”

Student A: “Take the seed out of the first apple and put it into the ground.”

Student B: “I think you have to take the seed out of the apple that Doug gave us, and you have to plant it... and you can... and more apple trees that make the same kind of apples.”

Student C: “Take the seed out of the sweet apple and plant it somewhere around your house.”

Student D: “You could cut it to the core and then you could get the seed.”

Student E: “You could buy a sweet apple and cut it to the core and take out the seeds and then you can plant them.”

Student F: “Earlier, when we were learning about flowering and non-flowering plants, I remember that seeds can be found in fruit and that if you plant those seeds... those seeds go into the ground then they make more of the exact same fruit that the animal can eat.”

This illustrates how Tali focused on her students’ ideas and thoughts. While many of these responses illustrated either misconceptions or an oversimplification of the process of selectively breeding apple varieties, she did not interject or correct. Instead she

illustrated her role as the learning guide and continued to push her students to reason through their own explanations.

Tali further demonstrated her role as the guide to learning by how she placed the emphasis on her students to develop their own ideas and definitions for the different concepts they were learning. For example, in the lesson on adaptations, Tali asked her students “what did we come up for a definition for what adaptations are?” Similarly, at the start of the lesson on light interactions, she directed her students to work in groups to “come up with your very own definition, your very own definition for refraction... I want it to make sense to you. Put it in your own words.” Both examples illustrate how Tali eschewed the traditional didactic role of direct instruction in favor of taking steps to guide her students through a sense-making learning experience where the responsibility is on them to figure out what these concepts mean to them in a way that makes sense.

Science-specific vocabulary.

In addition to the way all three teachers engaged their students in the authentic practices of scientists through how they employed the SEPs in the learning experience, Ashley, Miranda, and Tali also modeled and encouraged the use of science-specific vocabulary as a way to create a science-rich learning environment. Ashley communicated the expectation that her students would use science domain-specific vocabulary in both her interactions with her students and her expectations of their work, even to the point of explicitly stating “You are to use the vocabulary you’ve been using today.” Not only did she communicate this expectation during the lesson, she also explained why it is important that they be clear in their use of language, explaining “If you can use your vocabulary and explain it, then I know that you know what you are talking about.”

During all three observations, Ashley repeatedly stressed the need for her students to support their work, intentionally using the term evidence. When working with her students to support what they know about seeds, she said “Let’s talk about our evidence of what are seeds? Are there any evidence there?” During the lesson on characteristics of organisms, Ashley once more intentionally focused on the use of evidence, this time explaining how the student’s claim needs to be supported, explaining “So, either way, that’s however you saw that and you can back that up with evidence.” In the third observation, Ashley again put the emphasis on the use of evidence, once more intentionally using the terminology to communicate her expectations. “Where do the colors of the rainbow come from? Use evidence to support your answer.” Similarly, Ashley repeatedly and intentionally used the term “observation” when communicating her expectations to her students, such as when she explained how “Once we observe and collect the data, the evidence...” and “Based on your observations and your partner talk, what are you learning?” Such intentional use of science specific vocabulary, used in the context of student work and not merely as words to be memorized and learned, is an example of how Ashley used language to model the high expectations she has for her students to perform in the role of scientists. She even told her students as much when she said “I want you to be able to learn as you go, cooperate, collaborate, and talk the science language... We’re going to do some inferencing and drawing conclusions.”

Miranda also used science-specific language to create a science rich learning environment. In the first lesson, Miranda specifically communicated the scientific practices that her students will use when she tells them that they will “develop and use models to compare the stages of growth and development in various animals.” This is

also evident when she explained to her students that they need to “give me evidence to back it up.” In the third lesson, Miranda prompted her students to “Remember back at the beginning of the year when we talked about qualitative and quantitative observations and we’ve been making observations all year long. So what are some observations you can make?” Later on, she made the distinction between observation and prediction when she asked them “But could you observe that? So that’s a prediction. He’s predicting. I heard other people predicting it might be something you are familiar with. What’s another observation?” By employing specific science-language in her conversations with her students, Miranda was not only creating a science-rich setting, she was communicating her expectations that her students were to engage in genuine science practices.

Similarly, Tali created a science-rich learning environment through how she modeled the use and expectation of science-specific vocabulary, especially in terms of practices and inquiry. In the lesson about inherited traits, Tali focused repeatedly on the need for students to construct arguments and use evidence to support their claims, not only through the directions for the work but also through how she communicated and modeled the use of these terms. In so doing, Tali directly communicated her expectations that her students not only perform as scientists, but also think and use the language of science. In this exchange from the lesson on adaptations, instead of simply asking her students about their observations, Tali very specifically modeled the terms qualitative and quantitative as part of how she helps her students develop an understanding of the practices of science.

Tali: “Is that quantitative or qualitative?”

Student: “Qualitative because it has bubbles”

Tali: “Why is that ‘it has bubbles’?”

Student: “Because I can see bubbles.”

Tali: “What would quantitative be?”

Student: “Something with numbers. I could count the number of bubbles.”

All three teachers employed hands-on learning experiences to explore and engage in different scientific phenomena. Not only were many of the experiences the students engaged in hands-on in nature, they were well aligned with both the science content concepts and performance expectation of the SEPs of the state’s science standards performance indicators. Such intentional alignment between lesson activities and state standards-driven learning goals is a potential indicator of student achievement, particularly among traditionally low achieving learners (Marx, et. al, 2004; Rivet & Krajcik, 2004). Although hands-on alone does not make a learning experience inquiry in nature, for these teachers, the purpose behind these hands-on experiences was for students to experience the phenomenon and begin to attempt to make sense of it before being exposed to informational text sources that would serve to define and describe the phenomenon for them. In effect, the hands-on nature of the learning was for the purpose of developing an understanding of the phenomenon based on experiential learning through collecting observations, supporting claims with evidence and reasoning, engaging in model simulations, and constructing explanations. This approach to learning science is congruent with the characteristics of science inquiry in that it puts the focus on students investigating and attempting to construct their knowledge of scientific phenomena through the application of authentic science and engineering practices (SEPs) (Kim & King, 2012; NRC, 2012; Passmore, Stewart, & Cartier, 2009; Wu & Hsieh,

2006). In addition to these practices being observed during the course of the study, these teachers reported that they engaged their students in basic science practices, integrated science practices, and high sense-making activities almost 50% or more of the time during science instruction. This suggests that their students were engaged in a science-rich learning environment that focused on the use of authentic science practices with the aim of sense-making and knowledge construction the majority of the time in these teachers' classes. These teachers also explicitly focused on vocabulary as an important element of science learning, both in how they modeled its use and how they communicated their expectations for student use. This had the effect of inviting the learner to become a member of the authentic science culture in the classroom (Townsend, Brock, & Morrison, 2018).

The learning environments fostered by these teachers also bore many of the characteristics of social constructivism. All three teachers demonstrated an emphasis on sense-making through student discussions, often prompted by their questions (Chin, 2007; Cochran, Reinsvold, & Hess, 2017). The layout of the classrooms, with seating arranged to foster student group collaboration, the nature of the group activities, the explicit communication of the teachers regarding their expectations that students work collaborative, even the reported learning goals via the IPL-S all demonstrate an approach to learning that recognizes the social nature of knowledge construction and sense-making. (Chiatula, 2015; Faircloth & Miller, 2011; Tippett, 2009; Vygotsky, 1978). This is further reinforced by how all three teachers assumed the role of facilitator in the learning environment, eschewing the traditional role of knowledge authority (Brophy, 2010; Bryant & Bates, 2015; Doolittle, 2014; Tippett, 2009). Finally, all three teachers made

deliberate efforts to provide recognizable examples for their students and to make meaningful, relatable connections between their students and the science concepts as a way to foster engagement (Brooks & Brooks, 1999; Faircloth & Miller, 2011; Oldfather, 1993).

ANALYSIS OF OBSERVED CULTURALLY RELEVANT PEDAGOGY

Ashley, Miranda, and Tali all exhibit characteristics emblematic of culturally relevant pedagogy (CRP) in how they foster a positive, inclusive learning environment, chief among them being how they communicated and affirmed high expectations for student performance, showed how they valued student voice, and provided familiar, relevant connections with the science concepts. Furthermore, all three engaged in the use of positive classroom rituals and non-punitive measures to address student behavior in a way that created a safe place where students to engage in the inherent risk taking that is a part of an active learning environment.

Valuing student voice.

The importance of student voice is evident in the way Ashley, Miranda, and Tali often gave students the opportunity to share their ideas and understandings. Ashley frequently asked her students for their thoughts on what they knew about a topic when she first introduced it. When transcribing their responses, she did not correct misconceptions, nor did she impose her own interpretation over the words of her students. Instead, she made sure that what the students think is what was communicated for everyone in the class to hear. For example, when asking for their initial ideas about acquired and inherited characteristics, Ashley explained that “we’re gonna brainstorm about inherit, characteristics, and learned behavior. We’re gonna tap into your prior

knowledge, what you may know, what you may not know. But we're talking about inherit. What do you think we are talking about?" In so doing, she made it clear that it is *their* thoughts and ideas that were going to lay the foundation for the learning. In the following exchange, Ashley communicated that she valued their words by seeking to accurately capture what her students mean as opposed to her interpretation of that meaning.

Ashley: "So how you want me to write that?"

Student A: "A way for animals to survive in their habitat... A behavior that they learned based on failing from other types of behaviors."

Student B: "An adaptation learned, based on their habitat, their family, and where they go."

Miranda's classroom interactions also showed evidence for how she values student voice through students' opportunities to express their ideas without judgment or correction. This is illustrated through her routine use of questions to elicit student ideas and thoughts. She did not simply provide the scientifically accurate information through direct instruction. Neither did she impose her thoughts on what the students were trying to say. Instead, Miranda often revoiced her students' words and gave them a chance to share out their ideas. In the first lesson, on four separate occasions, Miranda invited her students to share out their ideas about their observations and reasoning. Many times, when a student described something or provided a reason, Miranda would paraphrase it for the sake of clarity. In this example, Miranda summarized how one of her students "noticed that on everybody's life cycle that she was looking at that on each stage each the drawing looked like a bigger version of itself." It is important to note that when she

revoiced a student's words, she did not try to correct misconceptions that may have become evident; though she sometimes used questions to help her students recognize their misconceptions. Similarly, in the lesson about mimicry, she asked a student what a predator is. The student responded by stating "an animal that... preys on its prey," to which Miranda revoiced "So an animal that preys on other animals."

Tali also exhibited the characteristics of CRP through her use of student discourse to foster a community based on equitable discussion and the value of student voice. For example, in both the lesson about adaptations and the lesson about light, the nature of the learning activities was designed for students to work collaboratively to articulate their own definitions and to make sense of the simulations they were engaging in and phenomena they were observing. In the adaptation lesson, Tali specifically communicated the need for students to work as a group when she explained how she was giving them "time in your group to figure out what a physical adaptation is and a behavioral adaptation is." This focus on sense-making through collaboratively engaging with phenomena was also evident in this exchange where students observed the image of an arrow viewed through a clear cup of water.

Student A (describing looking down at the arrow through the cup of water): "It looks like it's moving but if you go all the way down you can see it at the top"

Student B: "It refracts. It bends."

Tali: "Look at that, though. What do you notice? Is it pointing the same direction?" (Tali begins moving the arrow around, directing student attention.)

Student B: "No! It's pointing the different direction."

Student B: "Absorb!"

Student A: “No. No. Refract. It’s refracting.”

Both of these examples highlight how Tali empowered student voice and sense-making through collaboration and discussion. Additionally, in this way, she was not perceived as the source of knowledge. Rather, the students were able to recognize that they were not only responsible for but also capable of understanding the natural phenomena they were exploring.

The importance of student voice in Tali’s approach to teaching science was also evident throughout all three lessons in the way Tali seldom assumed the role of knowledge authority; rather, through her questions, she created a setting where students feel comfortable sharing their ideas. In this exchange from the lesson inherited characteristics, Tali asked the students to articulate in their own words what they had just learned from the video clip.

Tali: “Okay. It says, ‘How do we get from small crab apples thousands of years ago to large red and green apples today?’ I want just you to explain that to me. Use what Doug (video narrator) has said and tell me how do we get from the small apples to larger apples that are red and green”

Student A: “Selection over years they have figured out that they get bigger and bigger.”

Student B: “We rejected all the stuff that we didn’t like, and we selected all the stuff that were good... gooder ones.”

Student C: “People long ago, they decided they didn’t want the small ones no more, so they kept on waiting until they got bigger because they saw that they got bigger over time. So, they kept on waiting until they got bigger and bigger so then

they kept on making them. They were getting bigger and they started eating them and making more.”

Student D: “So back thousands of years ago people had crab apples and they started taking the seeds and using them to plant more. And one time they found bigger crab apples and they tried it and they tasted better. And then they cut it open and kept on planting it and they kept on choosing the selection of apples that got bigger and sweeter.”

Tali supported her students in taking the information from the video and putting it in their own words to illustrate their understanding of the content. Not only did this give Tali an opportunity for formative assessment, it demonstrated for the students that she wants to hear their ideas and thoughts in their own words.

Creating a risk-free environment.

Teachers who engage in CRP work to create a caring, supportive class setting where students can feel safe and supported in taking the inherent risks associated with an active learning environment. Ashley did a number of things that help to create a risk-free environment in which students feel comfortable sharing out their ideas and letting their voices be heard without fear of being singled out for making a mistake. When asking her students for their thoughts, she made it clear that the process was about hearing what everyone in the class had to say as they shared out their prior knowledge or their reasoning behind their explanations rather than about getting an answer right or wrong. For example, when she explained that “We don’t have to be afraid because this is just our learning. We’ll chart our learning here,” she was intentionally reassuring her students that they could feel safe taking risks in sharing what they think. In another instance, she

explained to one group of students during the seed-graphing activity, “I’m not worried about how good it looks. It’s about getting the skill of graphing as you count.” In the lesson about acquired and inherited traits, she explained how when they are brainstorming their ideas, “it’s not about right or wrong. It’s just brainstorming because once you get to start learning through the teaching, you get a little bit more clear about what you’re talking about.” She also communicated her expectation that it is acceptable to rely on one another when sharing out their information, for example “Help him out. What else do you think you know?” These examples highlight how for Ashley, it was important that she provided an environment where her students felt supported in taking risks in learning.

How Ashley addressed distracting and disruptive behavior was also indicative of how she creates a safe, risk-free learning space. Rather than taking punitive action when students disrupt the learning environment, Ashley invited them to consider their actions and the impact they have on the rest of the class. For example, in addressing a student who was being disruptive in his group, she asked him if he feels he “needs to be excused?” putting the responsibility on the student to consider his actions and their consequences. Similarly, during the station rotations of the second observed lesson, when a group of students was off task and not following directions, rather than getting upset or threatening, she matter-of-factly stated “Guys, you cannot proceed without following directions.” Once again, she was putting it on her students to decide how to correct their actions.

Miranda also broke down the distinctions between the power dynamics in the classroom and created a familiar, consistent, safe learning environment through her use of

positive rituals and routines. For example, Miranda employed the teacher-class call-and-respond ritual “[Teacher] One two three, eyes on me. [Class] Three two one, now we’re done.” to draw the class’ attention back to her when she was ready to engage them in some class discussion, typically following collaborative group work. Another example of how she created this positive learning environment is through how she had her students remind one another of the class routines and policies about collaborative group work. In the following exchange, asked her students to remind her of these expectations.

Miranda: “What are some of the things we want to remember when we are working with a group?”

Student A: “Stay quiet or stay silent”

Miranda: “When you’re working with a group you don’t want to stay silent because you want to communicate and collaborate with each other. But it should be at an inside voice. What else?”

Student B: “No fighting”

Miranda: “No fighting, that’s a big one. We want to cooperate and get along with the people in your group. Yes?”

Student C: “Respect the other people in your group.”

Miranda: “Respect the other people in your group. Good. Yes?”

Student D: “Don’t have an attitude and... and be nice to your other people around you so they’ll be nice back to you.”

Miranda: “Alright. Good.”

Another way in which Miranda created a safe learning space was through her use of non-punitive measures to address disruptions and distractions to the learning. During

the mimicry lesson, when a pair of students were engaged in a side-bar conversation, rather than discipline them for being a distraction to others around them, she questioned them on her expectations.

Miranda- “Hold on, freeze. What did I ask you to do?”

Student- “Write down what it taste like”

Miranda- “Write it down. We will share in just a second.”

In her life cycles lesson, when a student continued to work on some assignment from earlier, Miranda reassured her that was not worried right now if she did not finish it. In the following exchange, later in that same lesson, when addressing a student who was having a difficult time working with her peers, she gave her the option to select another group.

Miranda- “Do you want to join another group?”

Student- “I don’t want to”

Miranda- “Okay, so let’s try and work.”

Tali also created a positive learning environment through her use of positive classroom rituals and her non-punitive means of addressing student behavior. Tali frequently demonstrated the use of positive classroom rituals and procedures when calling the class together or when asking her students to remind her of her expectations for their work. On way in which she did this was by placing the emphasis on her students to illustrate that they could act in a responsible manner. For example, when she was transitioning from one activity to another, she said “Please be sure you are sitting next to somebody that you can be responsible by. If you think you can be responsible, then sit.” Not only did she quietly repeat this three times, she recognized students by name as they

meet her expectations until the entire class was ready. Another way in which Tali employs positive classroom routines was through a call-response ritual when she wanted to get her students' attention, such as when she said "Class, class, class" followed by a chorus of "Yes, yes, yes," or when she wanted to confirm that her students understood something by saying "Get it, got it, good?" followed by a student chorus of "Get it, got it, good!"

Tali also employed non-punitive measures when she was addressing student behavior. In a manner consistent with her interactions, she typically placed the focus back on the student to recognize when their behavior was not meeting her expectations. For example, when addressing such a behavior, she typically said something like "This is not acceptable. Do we understand each other?" Similarly, when a student had a basketball out in class, rather than directly address the behavior by chastising the student, she simply called attention to it by asking "That's yours?" In doing this, she pointed out that was the student's responsibility for correcting his actions in a way that did not draw attention to the disturbance or place the student on the defensive.

Communicating and affirming high expectations of performance.

In addition to her use of positive rituals and non-punitive actions to address classroom disruptions, Ashley created a supportive, risk-free learning environment through how she encourages her students' efforts in science. Ashley went to great lengths to communicate not only her high expectations, but also her belief that her students could achieve those expectations. Throughout her teaching, Ashley frequently noted when she was pleased with the work her students were doing, in particular the way they used different terms to describe something. For example, she often said things like "I like how

you used that word stone fruit,” “He was so sure. He knew that was a peach seed. He knew that,” and “I like how y’all sorting out seeds first.” Additionally, she often communicated her satisfaction with their overall performance and behavior by saying things like “Because you already know this!” and “I thank you all for a great lesson today.” When her students met her expectations, she was quick to celebrate their accomplishments in a manner that not only recognized their work, but helped them build a stronger sense of self-worth by connecting their hard work to their achievements.

In the following exchange, while showing the class the video on the nature of inherited traits, Ashley frequently stopped the video to compare the statements made on the video with the prior knowledge the students shared in their brainstorming early.

Ashley: “So inherit, you got traits coming from family. Could we say that’s pretty much accurate?”

Students: “Yeah!”

Ashley: “So we can pretty much say that was accurate.”

In the exchange, she was showing her students that their initial knowledge and understanding about the topic was aligned to the ideas presented on the video. In another example, Ashley quickly summarized the results of a short assessment she administered at the end of the lesson by stating “So, everyone is finished. So doing a quick assessment, So overall, about 94% of you all grabbed the concept of understanding inherited traits and learned behavior” Once again, she affirmed their efforts and ability to be successful.

Miranda also communicated her high expectations and affirmed student effort by offering positive feedback to her students. For example, in the first lesson, when inviting student groups to share out the common elements they observed when discussing one

another's life cycle models, she publicly described how one student "noticed that in everybody's, they're all growing and getting bigger...That's an interesting point I want you to hold on until later." In another instance, Miranda asked a student "Will you put yours up here so they can all see? It does look good. I love it." In the second lesson, after hearing a student's reasoning, she encouraged her to "keep writing. I like where you are right now."

Similarly, Tali created a positive learning environment for her learners through setting high expectations and providing meaningful affirmation for her students. Before starting a new activity, Tali communicated her expectations in a way that not only ensured her students understood the work, but also gave voice to her students.

Tali: "So for our critical thinking, what am I expecting? What am I expecting when I see your writing?"

Student A: "Scientific answers"

Student B: "A complete sentence"

Tali: "So that's what I'm expecting when I look your journals for critical thinking"

In another example from the same lesson, Tali not only communicated her expectations when she said "I am a scientist, right? Like we graphed our weather data, we'll graph our data," she also showed her students that they were assuming the role of scientists. During the lesson about light interactions, she once more reminded her students that they were assuming the role of scientists when she said, "When you talk to me as a scientist, you are going to say 'refract'."

In this exchange from the beginning of that lesson, during which Tali was walking her class through an unpacking of the state's performance expectation, she communicated to her class not only what they would be doing, but also, in a very direct manner, that she believed they were capable of doing more than the state's standards expects of them as 4th graders.

Tali: "On this sheet, it's called reflect, refract, transmit, and absorb investigation. Now there is one word that is not highlighted in your book and what word is that?"

Students: "Transmit"

Tali: "Transmit. Alright. Because that's not one of South Carolina's science words but I thought it went along with this so why not make us a little bit more smarter."

In addition to communicating her high expectations for their performance, Tali frequently provided recognition for her students when they met her expectations through phrases such as "Great connection," "I love all of this science vocabulary," and "That's a good observation." In this exchange from the first lesson, Tali asked for her students to share their ideas about the performance goal for the lesson.

Tali: "What does, first of all, construct a scientific argument mean?"

Student A: "Have different opinions of something."

Student B: "Like basically have different opinions and find out the answers."

Student C: "Everybody says their opinions and then we look at the life cycles and we can see what the answer is and we can see how the real answer and the answers we had are alike and not alike."

Tali: “I like those words”

Not only did Tali give her students an opportunity to show what they already understand about the nature of the standards-based learning, once again illustrating how she values student voice, she ended with affirmation for their understanding. By communicating both high performance expectations and affirmation for their work, Tali demonstrated that she believed that her students were capable of achieving in science.

Familiar, relevant examples and context.

The use of personally relevant and familiar connections is another element of CRP that overlaps with a social constructivist approach to teaching science. Ashley often drew upon examples that were familiar to the students in order to help provide context to what they were learning. In the following exchange from the lesson on inherited and acquired traits, Ashley directly referenced things that are familiar to her students.

Ashley: “So those are things they learn how to do... I like to play basketball. I didn’t come out knowing how to play basketball. I had to learn how to play basketball. I didn’t come out with a basketball in my hand. I had to learn how to do that.”

Students laugh at this.

Ashley: “Y’all kinda giddy today.”

In another example, she specifically included her students in a part of her example to help the class make connections to what they would be learning about.

Ashley: “So last night, when we had literacy night, I could see the physical characteristics of <Student A> and her mom. She looks just like her mother.

<Student B> looks just like her mom. So you see those physical characteristics that are passed on from their parents to their offspring, their babies.”

These examples illustrate how Ashley used personally relatable examples to help her students connect with science.

Miranda used stories and familiar examples as a way to help her students make a more personal connection with the science she was teaching. In the first lesson, she used pictures of herself and her sisters, including one of herself at the same age as her students, to help her students make a concrete connection to what they were learning about the different stages of an animal’s life cycle.

In this exchange, Miranda was attempting to help a student understand the distinction between acquired and inherited traits.

Miranda: “Look I have a scar right here. See that? Yeah when I was in sixth grade, I bent down next to my book bag and a pencil or I think it was a pencil or pen poked me in the knee and I got a scar.”

Student: “Is a birthmark a scar?”

Miranda: “That’s something you’re born with. See this right here (shows forearm). I’ve had this since I was born. When I was born this was on my arm. Now this scar... Was I born with it? I got it in the sixth grade so was I born with it?”

By using herself as an example, she made the abstract idea of acquired traits familiar to her student. She did this again when she offered to video record her dog’s behavior as a way for her students to see an example of how her dog learned when it would be feeding time.

Similarly, Tali used connections between herself and her family in showing students examples of inherited traits. This had the effect of not only helping them understand what they would be doing for their homework that evening regarding inherited traits in their own families, it also helped make the abstract concepts of inherited characteristics in organisms more familiar and relatable. In making these personal, relatable connections, both Miranda and Tali are working to make the learning meaningful and relevant to their students.

Collaborative nature of authentic science practices.

Certain science and engineering practices (SEPs) lend themselves naturally to the social nature of learning through collaborative sense-making, chief among them being obtaining, evaluating, and communicating information, constructing explanations and designing solutions, developing and using models, and engaging in argument from evidence (Brown, 2017). As described earlier, all three teachers often engaged their students in the use of authentic SEPs, in particular analyzing and interpreting data, constructing explanations, developing and using models, and obtaining and communicating information. Additionally, elements of engaging in argument from evidence were also present when their students use evidence from their experiences, observations, and simulations to support their reasoning. In the cases described earlier, the way Ashley, Miranda, and Tali did this was through collaborative work where students interacted with one another in a way that fostered sense-making dialogue.

Not only was this focus on collaborative learning evident in the use of specific SEPs, it was also reflected by how the classrooms were arranged to allow students to work in small groups as a matter of routine. Furthermore, in all nine observed lessons,

these teachers engaged their students in group learning experiences where they were expected to work with one another to make sense of the phenomenon they were studying. This was particularly evident in Ashley's lesson on inherited and acquired traits, in Miranda's lesson on mimicry, and in Tali's lesson on adaptations and survival. In one example, Miranda went so far as to explicitly remind her student that their work was to be done collaboratively when she allowed them to talk out loud as they work; "When you're working with a group you don't want to stay silent because you want to communicate and collaborate with each other. But it should be at an inside voice."

Overlapping Characteristics between CRP and Science Inquiry.

It is worth noting that many of the characteristics that create a positive, culturally responsive science learning environment also reflect elements of a social constructivist approach to teaching science. In assuming the role of facilitator, Ashley created a science-learning culture in which she was not perceived by the students as the source of knowledge. In so doing, she disrupted the traditional approach to teaching science by emphasizing that it was through their actions as young scientists that students would develop their understanding and construct their new knowledge through sense-making. Ashley emphasized this point with her students when she reminded them that they were engaging in exploring to learn science, such as at the start of the lesson on white light when she explained "I'm going to let you explore and get the information. I want you to be able to learn as you go, cooperate, collaborate, and talk the science language... We're going to do some inferencing and drawing conclusions." In making this statement, she informed her students see that their explorations were how they will come to develop their understanding, not by reading it in some book. Even though in this example, her

students did read a short passage on light, Ashley made no effort to unpack the text to help them understand it. The emphasis of the lesson was clearly on exploring the phenomenon as a means by which to eventually figure out what was going on. As described earlier, Ashley frequently made statements that emphasized how learning science takes place through sense-making, where the process is as important as the knowledge that is being constructed.

Miranda's use of questions to elicit student ideas and reasoning also reflected characteristics of CRP. In all three observed lessons, she engaged in the use of clarifying questions when she wants her students to explain what is going on. For example, when Miranda asked a student what the liquid smells like in the mimicry simulation, she used her questions to push him for greater detail regarding his description. "What do you mean it smelled like Cola? What do you mean...did anyone have anything different for what it smelled like? Because if you are an animal, you may not know what Cola is. What did it smell like?" In this example, she did not tell the student that he is incorrect for making this response. She used her questions to get him to provide more detail and reasoning behind his response. Emblematic of how Ladson-Billings (1995) defines the qualities of CRP in teachers, her work was that of pulling knowledge out of the students, not pushing it in.

Tali's manner of teacher also challenged the traditional classroom power dynamic of the teacher as the knowledge authority and students as the recipients of that knowledge. She did this assuming the role of facilitator in the classroom and placing the emphasis on learning through active participation in the learning experience and sense-making. This, in turn, invited the students to be a part of the classroom culture in a way

that allowed their cultural identities to play a role in the learning process. Additionally, her use of questions to probe her students' ideas fostered a sense-making environment in which her students engaged in discussion to develop their understanding.

These examples illustrate the different ways that the three teachers displayed many of the characteristics of CRP. All three teachers demonstrated how they use questions to elicit students' ideas, probe students' understanding, and give voice to student thinking (Chin, 2007; Cochran, Reinsvold, & Hess, 2017). The use of teacher questions to promote student discussion is indicative of a teacher who values student voice and places an emphasis on the importance of the student being in the role of knowledge construction (Brown & Crippen, 2016; Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995). These teachers also provided positive reinforcement through the feedback they provide, through how they communicate high expectations, and through how they recognize and celebrate when their students meet their expectations. These interactions helped students connect their efforts with their successes and offered a visible way of communicating to their students their belief in their capacity to be successful in learning science (Forsyth & McMillan, 1981; Ladson-Billings, 1995; Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995). Ashley, Miranda, and Tali all employed various positive rituals and routines, as well as engage in non-punitive actions when addressing disruptive behavior. In this way, they create a positive classroom culture where students can feel safe and free to take the risks inherent in being an active learner. Additionally, these steps helped break down the metaphorical barrier that can exist between the culture in the classroom and the cultural

identities of the students (Ladson-Billings, 1995; Phelan, Davidson, & Cao, 1991; Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995).

It is important to point out that several of the practices these teachers employ were congruent across science inquiry, social constructivism, and CRP. The use of relatable, relevant connections by these teachers not only fostered engagement in science, it also helped students see the how what they were learning is connected to their own lives in a familiar way (Grimberg & Gummer, 2013; Ladson-Billings, 1995; Laughter & Adams, 2012; Lee, 2004). The way these teachers focused on sense-making was not only emblematic of knowledge construction, it also helped to students identify with their role as the ones who would be constructing their own understanding, something that further made the learning personally meaningful (Grimberg & Gummer, 2013; Lee, 2004; Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995). Finally, the very nature of engaging in authentic SEPs as a means by which their students learn science through inquiry practices created a positive, collaborative learning community in which their students could the belonged (Brown, 2017).

ANALYSIS OF IPL-S RESULTS

In an effort to capture the routine practices, learning goals, resources employed and the frequency and duration of science instruction among the participants, Ashley, Miranda, and Tali all engaged in the Instructional Practices Log for Science (IPL-S) over the course of the study. This log, designed as a means of capturing self-reported data about the instructional practices of elementary science teachers, allows teachers to record the content they covered, the duration and frequency of science instruction, the learning goals, the instructional resources, and the various instructional practices they engaged in

on any given day (Adams, et. al., 2017). While the participants were given the opportunity to use an online form to complete this log over the course of a 45-day period, the number of entries varied with each participant, with Ashley completing the IPL-S on 28 occasions, Miranda completing it on 25 occasions, and Tali doing so on 34 occasions.

Frequency and duration of science instruction.

Over the course of the 28 days for which Ashley reported on her instruction, she indicated that she taught science 17 of those 28 days, or 60.7% of the time. During the 17 days where Ashley indicated that she taught science, the reported duration of her science instruction ranged from 30 minutes to more than 60 minutes, with her most frequent lesson duration being 60 or more minutes reported 9 times. On two days, she reported a duration for science instruction even though she had indicated that she did not teach science on those days. For the sake of calculating the average number of minutes of science instruction, these two instances are being considered 0 minutes of science instruction.

Over the course of the 25 days for which Miranda reported on her instruction, the reported duration of her science instruction ranged from 30 minutes to 50 minutes, with her most frequent lesson durations being 35 minutes, reported seven times, and 40 minutes reported eight times.

Finally, for the 36 days Tali reported on her instruction, she indicated that she taught science 25 of those 34 days, or 73.5% of the time. During the course of the 25 days where Tali indicated that she taught science, the reported duration of her science instruction ranged from 30 minutes to more than 60 minutes, with her most frequent lesson duration being 30 minutes reported 13 times. On six days, she reported a duration

for science instruction even though she had indicated that she did not teach science on those days. For the sake of calculating the average number of minutes of science instruction, these two instances are being considered 0 minutes of science instruction.

For both Ashley and Tali, the reasons given for the days in which they indicated they did not teach science are presented at the end of this section. Figure 4.1 represents the frequency of the duration the three teachers reported teaching science.

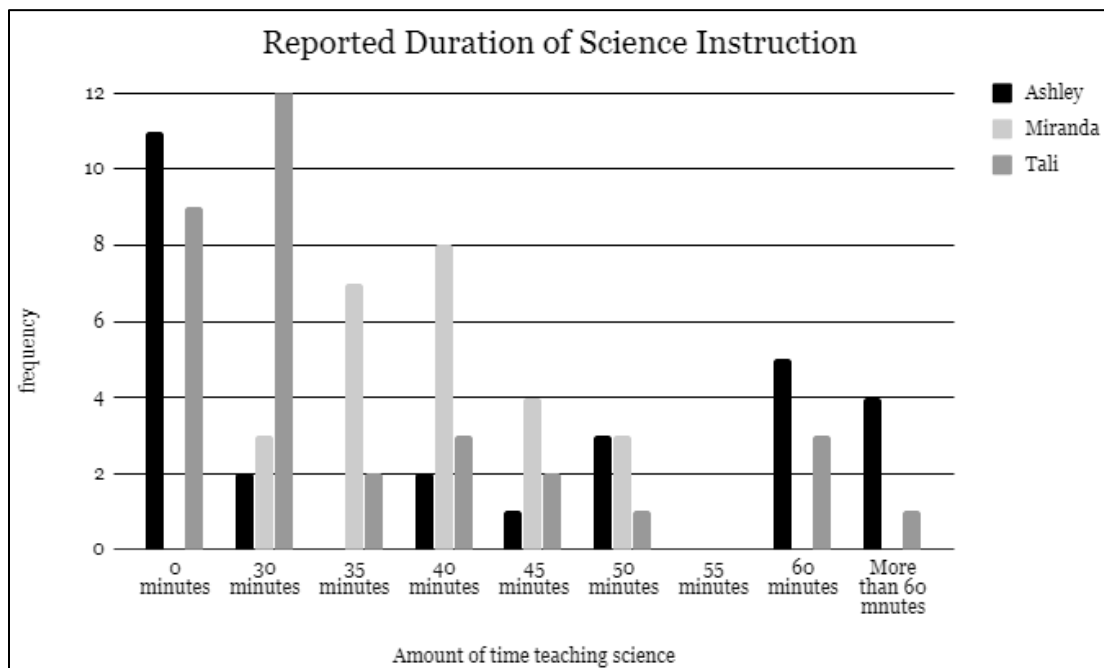


Figure 4.1 Reported duration of science instruction

Over the 17 days during which Ashley indicated science instruction took place, the total combined minutes of science instruction were 935 minutes science instruction, for a mean duration of science instruction of 55 minutes per day during the 17 days for which science instruction was reported, or approximately 275 minutes per week. The

mode for the duration of science instruction was 60 minutes. The median was 60 minutes. When all 28 days are factored in, the mean duration drops to 33.39 minutes of science instruction per day. This results in an average of 166.96 minutes or 2.78 hours of science instruction per week.

Miranda taught science for a total combined duration of 985 minutes, for a mean duration of science instruction of 39.4 minutes per day during the 25 days for which science instruction was reported, or approximately 197 minutes or 3.28 hours per week. The mode for the duration of science instruction was 40 minutes. The median was 40 minutes.

Over the 25 days during which Tali's science instruction took place, the total combined minutes of science instruction were approximately 965 minutes science instruction, for a mean duration of science instruction of 38.6 minutes per day during the 25 days for which science instruction was reported, or approximately 193 minutes per week. The mode for the duration of science instruction was 30 minutes. The median was 30 minutes. When all 34 days are factored in, the mean duration drops to 28.38 minutes of science instruction per day. This results in an average of 141.91 minutes or 2.37 hours of science instruction per week.

Figure 4.2 illustrates the mean duration of science instruction in terms of hours per week for all three teachers.

Science content reported.

Overall, the participating teachers primarily reported that they taught lessons related to plants and animals for most of the time they recorded the science content they taught. For 14 of the 17 days Ashley reported teaching science, she indicated that the

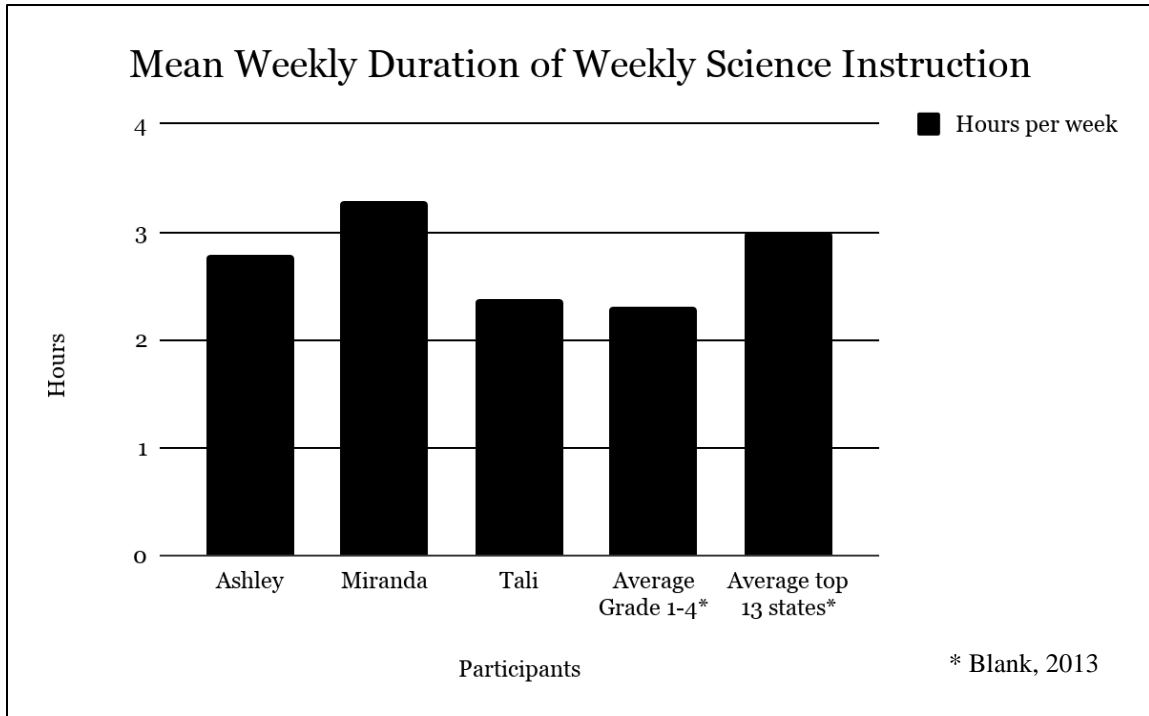


Figure 4.2 Mean weekly duration of science instruction

subject was plants and animals, including heredity. Miranda reported teaching about plants and animals for all 25 days, in some cases specifying heredity and adaptations. Finally, Tali taught about plants and animals on 23 of the 25 days she reported teaching science.

Additionally, Ashley also reported teaching about energy, sound, and light on three days while Tali reported teaching about the Solar System on two days.

Instructional goals reported.

Over the course of the 28 days for which Ashley reported on her science instruction, she identified specific primary and secondary instructional goals a total of 62 times. Miranda identified specific primary and secondary instructional goals a total of 54

times during the 25 days she reported her on science instruction. And Tali reported primary and secondary instructional goals a total of 67 times over the course of 34 data entries. Table 4.1 shows the frequency of specific learning goals identified by the teachers.

Table 4.1 Frequency of primary and secondary science goals

Primary and Secondary Science Goals	Ashley	Miranda	Tali
Apply science to real world problems	3	6	4
Closed notes to put all ideas together	0	0	1
Connect science concepts to everyday life	6	9	8
Cooperate with others	10	7	12
Develop children's interest in science	7	0	12
Develop laboratory skills and techniques	5	1	0
Develop reading comprehension skills	8	4	11
Develop scientific writing skills	0	1	0
Develop test taking skills	1	0	9
Exploration	1	0	0
Identify cause and effect in scientific phenomena	4	2	0
Identify differences and similarities in scientific phenomena	6	3	2
Learning about the relevance of science to society	2	7	0
Make inferences based on scientific knowledge or data	4	3	2
Observe patterns in science	4	8	5
Practice science safely	1	0	0
Review for assessment	0	0	1
Understanding the scientific method	0	3	0

Note: Bold-faced items are identified by the designers of the IPL-S as being high sense-making science activities (Adams, et. al., 2017).

Out of the 62 science goals Ashley reported, high sense-making science activities were identified as goals 34% of the time. These results are consistent with Ashley's

observed manner of teaching. That she would indicate that her most frequent learning goals are that her students “Cooperating with others,” “Develop reading comprehension skills,” and “Develop children’s interest in science” supports her manner of teaching science through collaborative grouping, as well as her focus on the use of science-rich vocabulary and her deliberate efforts to have her students see themselves in the role of scientists when they do their work.

Out of the 54 science goals Miranda reported, high sense-making science activities were identified as goals 41% of the time. These results are consistent with Miranda’s observed manner of teaching. That she would indicate that among her most frequent learning goals are “Connect science concepts to everyday life,” “Learning about the relevance of science to society,” and “Apply science to real world problems” supports her manner of teaching science as Miranda frequently draws connections between what she is teaching to her students or what her students are doing and real-life examples that her students can relate to.

Out of the 67 science goals Tali reported, high sense-making science activities were identified as goals 19% of the time. These results are consistent with Tali’s observed manner of teaching. That she would indicate that her most frequent learning goals are that her students “Cooperating with others,” “Develop reading comprehension skills,” and “Develop children’s interest in science” supports her manner of teaching science through collaborative grouping, as well as her focus on the use of science-rich vocabulary and her deliberate efforts to have her students see themselves in the role of scientists when they do their work.

Instructional resources reported.

Over the course of the 28 days for which Ashley reported on her science instruction, she reported using eight distinct types of resources during science instruction employed on a total of 31 occasions. Of these resources, four of them were used the bulk of the time, accounting for 87.1% of usage. These resources were photographs related to sciences ideas, science textbooks, videos or video clips about science ideas, and scientific objects or specimens. For the 25 days Miranda completed the IPL-S, she reported using ten distinct types of resources during science instruction employed on a total of 36 occasions. Of these resources, six of them were used the bulk of the time, accounting for 83.3% of usage. These resources were photographs related to sciences ideas, diagrams of science ideas, videos or video clips about science ideas, science textbooks, scientific objects or specimens, and on four occasions the resources she used were not listed among those on the IPL-S. Finally, Tali reported using seven distinct types of resources during science instruction employed on total of 41 occasions. Of these resources, five of them were used the bulk of the time, accounting for 95.1% of usage. These resources were science textbooks, diagrams of science ideas, photographs related to science ideas, videos or video clips about science ideas, and on ten occasions the resources she used were not listed among those on the IPL-S.

Table 4.2 shows the frequency of the different instructional resources the teachers reported using.

While Ashley indicates the use of the science textbook 25.6% of the time, her use of photographs, video clips, and science object and specimens support her patterns of teaching science through authenticity and real-world connections. Similarly, Miranda's

Table 4.2 Frequency of reported instructional resource use

Resources	Ashley	Miranda	Tali
Diagrams of science ideas	1	6	8
Online or print science encyclopedias	0	1	0
Photographs related to science ideas	9	8	5
Science computer simulations	0	1	0
Science fiction trade books	1	0	0
Science kits	1	0	0
Science newspapers or magazines	0	1	0
Science nonfiction trade books	0	1	1
Science textbooks	8	4	12
Scientific objects or specimens	5	4	1
Videos or video clips about science ideas	5	6	4
None of the above	1	4	10

use of photographs, video clips, diagrams, and science object and specimens support her patterns of teaching science through authenticity and real-world connections, accounting for 66% of instructional resources she used with her students. And although she indicates the use of the science textbook 29.3% of the time, Tali's use of photographs, video clips, and science object and specimens support her patterns of teaching science through authenticity and real-world connections.

Instructional practices reported.

Over the course of the 28 days for which Ashley reported on her science instruction, she indicated that she employed various science-related student activities on a total of 123 instances. Miranda indicated that she employed various science-related student activities on a total of 212 instances over the 25 days she completed the IPL-S.

And Tali reported that she employed various science-related student activities on a total of 187 instances over the course of 34 entries.

Of the science-related student activities identified by the three teachers, Table 4.3 classifies those activities based on how they are defined on the IPL-S as belonging to one of five categories: low sense-making, high sense-making, communication, basic practices, integrated practices (Adams, et. al, 2017).

Of the science-related student activities the teachers reported, many of the occurrences were for activities that are not classified into one of the five categories listed for the IPL-S (Adams, et. al., 2017). Their inclusion on the instrument was intended to capture the spectrum of possible activities that the students might engage in while learning science and, in some cases, it would not be possible to determine the caliber of the activity without knowing additional details.

Factoring in the 21 instances of high sense-making activities listed under the learning goals section of the IPL-S, Ashley engaged her students in low sense-making activities 9.0% of the time and high sense-making activities 26.4% of the time. Additionally, students engaged in communication science activities 10.4% of the time, basic science practices 18.1% of the time, and integrated science practices 1.4% of the time. The remaining 50 occurrences of reported science-related student activities are not classified by the IPL-S and account for 34.7% of the reported student activities.

Similarly, when factoring in the 22 instances of high sense-making activities listed under the learning goals section of the IPL-S, Miranda engaged her students in low sense-making activities 14.1% of the time and high sense-making activities 22.2% of the

Table 4.3 Frequency and classification of reported science-related student activities

Reported Science-Related Student Activities	Ashley	Miranda	Tali
Total	123	212	187
Low sense-making activities	13	33	36
Explain their thinking to see if they are “getting it”	2	12	11
Learn science vocabulary or scientific facts	5	5	12
Recall information from previous lessons	5	16	13
Research a science topic	1	0	0
High sense-making activities	17	30	8
Compare multiple explanations of a science ideas	0	1	0
Examine scientific claims made by others	1	2	1
Explicitly connect today’s learning to their prior knowledge	8	16	2
Share scientific explanations with other students	2	6	1
Support their thinking with evidence	6	5	4
Communication activities	15	37	23
Communicate information using models, drawings, writing or numbers	2	0	1
Discuss science ideas	3	19	11
Label parts of objects, cycles, or systems	3	3	2
Make drawings or diagrams	2	2	2
Summarize learning about a science idea	2	8	3
Write about or illustrate science ideas	3	5	4
Basic science practices	26	46	34
Conduct a hands-on activity or manipulate materials	5	7	7
Display data in tables or graphs	1	3	4
Examine scientific objects or specimens	4	7	1
Follow appropriate steps in an activity	4	5	4
Formulate scientific questions	0	1	0
Make observations	5	7	9
Make predictions to forecast future events	1	3	1
Organize or record scientific information	1	0	0
Record data	3	7	4
Take measurements	0	3	4
Use tools or instruments	2	3	0
Integrated science practices	2	5	0
Develop and plan to test a hypothesis	0	2	0
Generate hypotheses based on scientific facts	1	2	0
Manipulate a variable in an experiment	1	1	0

Table 4.3 Frequency and classification of reported science-related student activities (continued)

Reported Science-Related Student Activities	Ashley	Miranda	Tali
<i>Unclassified science practices</i>	50	61	83
Complete science worksheets	2	2	7
Go outside to learn about science	1	1	3
Label parts of objects, cycles, or systems	0	1	0
Listen to the teacher explain science concepts	15	15	25
Play a science game	5	0	2
Present or watch other students present oral science reports	0	0	1
Read or listen to science reading	9	14	16
Take a science test or quiz	1	1	3
Take science notes	7	8	17
Use overarching concepts to draw connections between different science topics	1	2	4
Use results to address a scientific question	2	1	0
Use science related internet resources or software	0	5	0
Watch a science demonstration	2	1	2
Watch a science video or video clip	5	10	6

time. Additionally, students engaged in communication science activities 15.8% of the time, basic science practices 19.7% of the time, and integrated science practices 2.1% of the time. The remaining 61 occurrences of reported science-related student activities are not classified by the IPL-S and account for 26.1% of the reported student activities.

When the non-defined activities are factored out, the frequency with which Ashley engages her students in high sense-making activities rises to 40% of the time. Additionally, the frequency with which she engages her students in both basic and integrated science practices rises to 29.8% of the time. For Miranda, when the non-defined activities are factored out, the frequency with which she engages her students in high sense-making activities rises to 30.1% of the time and the frequency with which she

engages her students in both basic and integrated science practices rises to 29.5% of the time. These results are consistent with the constructivist science inquiry classroom environment Ashley and Miranda create when they teach science, one in which students are tasked with figuring things out and supporting their conclusions with evidence and reasoning through the application of authentic science practices (Brooks & Brooks, 1999; Chiatula, 2015; Faircloth & Miller, 2011; Tippett, 2009; Vygotsky, 1978).

The results of the IPL-S suggest that Tali does not engage her students in instructional activities that are classified as high sense-making as often as Ashley and Tali. Factoring in the 13 instances of high sense-making activities listed under the learning goals section of the IPL-S, Tali engaged her students in low sense-making activities 18.0% of the time and high sense-making activities 10.5% of the time. Additionally, students engaged in communication science activities 11.5% of the time, basic science practices 17% of the time. The remaining 83 occurrences of reported science-related student activities are not classified by the IPL-S and account for 41.5% of the reported student activities. When the non-defined activities are factored out, the frequency with which Tali engages her students in high sense-making activities rises to 18% of the time. Additionally, the frequency with which she engages her students in basic science practices rises to 29.1% of the time.

Reasons reported for non-science days.

Ashley indicated she did not teach science on 11 out of the 28 days for which she reported her instructional practices, or 39.3% of the time. Tali indicated she did not teach science on 9 out of the 34 days for which she reported her instructional practices, or

26.4% of the time. For the 25 days that Miranda completed the IPL-S, she indicated that she taught science every single time.

Table 4.4 illustrates the reasons during which the teachers did not engage in science instruction.

Table 4.4 Frequency of reasons reported for not teaching science

Reasons for non-science instructional days	Ashley	Tali
Early dismissal	1	0
Field study or guest speaker	3	1
Substitute teaching the class	0	6
Teaching math	1	0
Teaching social studies	3	0
Testing or benchmark testing	3	2

It is also noteworthy that Ashley indicates that only four out of the eleven occasions during which she noted not teaching science are related to teaching other content areas. In the larger context, of the 28 days for which she reported her instructional practices, Ashley taught other subjects in lieu of science only 14.3% of the time. This illustrates that Ashley places a priority on science instruction and seldom puts other instructional priorities in front of science. Interestingly, although Tali reported not teaching science on nine of the days, none of them were for teaching other content areas. When viewed in conjunction with the mean duration of Tali's science instruction, it suggests that while Tali may teach science for a reduced amount of time in order to address math content, she does not make it a practice to cancel science instruction over

the need to teach math. These data illustrate that both Ashley and Tali place a priority on science instruction and seldom puts other instructional priorities in front of science.

ANALYSIS OF TEACHER BELIEFS AND ATTITUDES

The beliefs and attitudes attributed to Ashley, Miranda, and Tali with regard to teaching science as well as their feelings about their students reveal many similarities among how the three teachers view teaching science through an inquiry-driven approach as well as how and why they work to create a culturally relevant learning environment for their students.

Influences and experiences that impact feelings about teaching science.

Ashley's approach to teaching science is grounded in her own personal experiences and feelings about science in general. Growing up in a rural area, her education did not stress math and science. In reflecting on this, she stated that "those were two areas that I struggled with," resulting in the feeling that she was not very strong in those areas, feeling "a little iffy about science and math." Because of this, her approach to her professional growth was driven by a desire to be a great teacher for her students so that she could prepare them "to be great teachers and leaders later on in life." In turn, she pushed herself to learn science in a manner that can help her make ensure that her students did not have the same perception about science that she had growing up. This also accounted for her seeking out professional development (PD) on how to provide more hands-on experiences for her students as well as how to unpack and understand the learning goals and performance expectations of the state's science standards in a way that relates to how "we teach them every day." Because of her efforts at improving her science background knowledge and skills, she is "liking science a lot more," especially as

she has “learned to dig into it and really understand.” She welcomed these experiences and felt that even though she has been teaching 4th grade for five years, the more she was able to study the standards, the “better I get it.”

Ashley’s feelings about teaching science have evolved over time, with her starting out feeling nervous about it, owing to her own limited science and math experiences from childhood through college. However, when she started teaching 4th grade, she worked with a teacher who became a mentor to her and helped her make science applicable to her students. This mentorship, along with her self-described natural curiosity, helped her overcome her fear and drove her to take the initiative in providing hands-on learning for her students in science. It was significant that Ashley described this and other opportunities for her to learn and grow as opportunities to “understand it and then to be able to give that to my students.”

Miranda’s feelings about teaching science were influenced by both her own lack of experience with science as well as her students’ reactions to learning science. Miranda explained that because she did not have a strong science background, science “kinda scares me a little bit.” She felt “there is a lot of information that you need to know and a lot of... you really have to study the material and understand.” In particular, when describing astronomy, one of the four main science units in 4th grade, “astronomy is very abstract for them and to be able to explain that you have a solid understand of what is happening.” At the same time, she enjoyed teaching science, explaining that “I like it because they love it... It makes me excited to do it because they love it so much.” She described her entire class as getting excited any time they know they are moving into science, even if they are just reading about science. In reflecting on this, she felt

“something I’ve done has made them really love science. I don’t know that there is a kid in my room who doesn’t like learning science, which is kinda cool.” She explained that as a whole class, they do not show this same level of unanimous enthusiasms for any other subject.

Miranda also described how she feels a strength of hers is “pulling in things that are relevant and real for them... making a connection to something different but that still applies that can help them understand the concept in a different way and give them something to remember.” She felt that this also helps her students by “giving them experiences because a lot of them don’t have experiences to pull from, background knowledge to pull from.”

Miranda’s feelings about science also stem from positive support and professional learning she has received from the researcher in his role as the school district’s elementary science content specialist. In describing a PD session the content specialist provided during a grade level meeting at Normandy Elementary School earlier in the school year, Miranda explained how he guided the grade level team through reflecting on the work they had recently done with their students on the water cycle. In this PD, the content specialist examined the work their students had produced and unpacked it by taking “something we had created and worked hard on and tweaking it a little bit in order to make it a little bit better, a little more inquiry based.” She explained that this professional learning “had more authenticity because it was something we had already been doing and worked to create and put together ourselves and then to use that, rather than you saying ‘you could have done this and this’ but taking something we had already done and then just fixing it just a little but not just completely throwing out something we

had already done.” Besides these at-school grade level science meetings, she did not feel as though she has had many other meaningful science training, though she did state that at previous district inservice training sessions, she would try to seek out at least one science-related workshop. Beyond that, she said that what she had learned about implementing her state’s elementary science standards she “had to do it on my own and figure it out.”

Tali’s attitude towards teaching science had evolved over the past eight years she has been involved in elementary education, including her time when she was student teaching. Her initial perspective was informed by an experience at a school in which she felt “everything was rosy, and everything was easy... science seemed like we did PowerPoints, got test scores back, the kids did well.” However, once she had a class of her own in a different school district, she later realized that her initial experience gave her a false sense of how best to teach not only science but all content areas. In terms of her science education coursework, she felt her it focused more on the “philosophies of teaching but not necessarily the ‘how to teach’” without much concrete experiences on how to teach science. During her first four years of teaching, before she was hired at Grissom Elementary School, she taught 5th grade, though she did not teach science. What science she did experience was taught by a science lab teacher in a lab setting where the students engaged in science exclusively through a kit-based curriculum. She would not teach science until her second year at Grissom Elementary School, her sixth year as a certified teacher. During this time, Tali described how she “never liked science. It was one of those things I prayed I never had to teach.”

Tali's approach to teaching science changed significantly following a professional development experience she received during the 2016-2017 school year. This PD, provided by the research in his role as the district's elementary science content specialist, focused on teaching the science behind the state's science standards; in the case of this particular session, the focus was on astronomy. Tali described how the part of the PD that modeled the Phases of the Moon stood out and "is why I do science the way I do this year" because how the PD made "it real life for us." In terms of how it affected her teaching, "it helped me better understand it to explain it to my kids and help them better see the process." In comparing how she taught now to her previous year, she explained how previously she would "start with the beginning of the school year with 'kids I'm sorry. This is not the type of science that's all hands... this is more about how the Earth works so there's not a bunch of concrete things. This is more big-ideas.' I think that turned them off at the beginning." In contrast, she explained how the way different concepts were modeled in the workshop showed her how she could make her science teaching more interactive and hands-on as opposed to a more text-heavy focus on science teaching. She also described how after this experience, she began to take the initiative to "research ways to make this science hands on," more active and hands on for her students."

Another PD experience that shaped the way she now approaches science also came from the district's elementary science content specialist when he met with her grade level team earlier in the current school year. This PD focused specifically on text dependent questions that tied directly to the different performance indicators and performance expectations of the standards. She explained that this PD helped her see how

she could “make the connection between the questions with the standards,” a practice she has brought into her classroom.

Tali’s attitude towards teaching science changed significantly in the past year. She had “actually grown to like science” as a result of the PD she had received in the past two years, especially “at making the connection with my students.” She felt more confident in her abilities because she “had to learn it for myself, for my students, in order to teach it to them... it helps me teach them better for them to understand because I have to break it down for myself in order to break it down for them.” She went on to explain that one of her strengths in teaching science was “having the ability to be creative when it comes to showing them different concrete examples... also trying to make connections with what happens in real life or everyday life for them.”

It is important to note that the PD experiences delivered to these teachers by the researcher in his role as the school district’s elementary science content specialist were not exclusive to the study’s three participants. The school-based PD these teachers described taking part in was part of a professional learning experience that was routine in the school district, often coordinated with each school’s administrators, and delivered to an entire grade level at a time. Additionally, after the school PD described by these teachers was voluntary in nature and offered any interested teacher in the school district. Finally, all of these professional learning experiences were delivered prior to the selection of the three participants.

Feelings about the role of questions and discussions in learning science.

Ashley felt that her students learn science best when they were engaged in conversation, when they were the ones talking about it, sharing their thoughts and ideas,

“them talking about what’s going on, voicing their misconceptions, asking those questions, why? why? why?” She frequently made use of questions, both her own and by providing opportunity for students to voice their questions, to foster discussion. Not only did she use her questions to spur discussions, but she felt that it is through these question-provoked discussions that her students were able to develop an understanding of what they are learning. Through her questions and discussions, Ashley also focused on key terms and vocabulary. In particular, she focused on the use of evidence. “A lot of time I’ll tell them ‘you all are giving me answers, answers, answers. But you have nothing to back that up with and as a scientist if you’re going to try and help someone you have to be able to back stuff up’.” Reading was also part of her science lessons, both in terms of times she read to them as well as when her students read. She frequently had them work in peer groups to foster discussion and collaboration. Together, Ashley intentionally used student discussions and questions to foster engagement on the part of all of her students.

Additionally, through her questions and opportunities for student discussions, Ashley felt she could both identify persistent misconceptions where she might need to redirect or re-teach something, and assess how well her students were developing their knowledge. “As they’re talking, I’m processing as well, this kid is getting this and I can say, ‘You know what, I heard this in this group’. What is the misconception here? And I’m asking them questions. ‘What are you not understanding? So talk to me about what you don’t understand so I can help you’.”

Discussion and conversation also played a key role in Miranda’s classroom. In terms of how she assessed her students’ understanding, Miranda described a variety of formative assessment strategies that she employs, chief among them being to how she

structured much of her science lessons around “an open discussion” about what they were learning. In this way, she explained, she was able to check for understanding, listen for any misconceptions, and identify areas where she might need to reteach some part of the concept. This is something she described as “formative assessment through discussions” where their investigations acted as an “open floor for you to say your question, tell me what you’re think and we kinda bounce ideas off each other.” Miranda also described using exit slips as well as online polling at the end of a lesson to have her students respond to one or more prompts that required they summarize the main “takeaway” from the lesson as an additional means by which she was able to check for understanding.

Tali used overarching questions to help her students connect with the science concepts and to spur discussion. She also used questions throughout the lesson and when working with their textbooks that require students “find supporting evidence as to why for the answer to that questions.” Tali explained that questions were how she gets her students to “think about it while they are doing it.” Questions played a major role in how Tali assessed her students’ understanding of science concepts. She described how she used questions to not only get answers but also to push for evidence of understanding by how she asked students to give more detailed explanations or show their reasoning behind their answers. “Usually if they can explain then I know that they have it or ask them to give me examples.” Additionally, she added that “a lot of times I’ll take their journals and look at what they’ve said in their labs to see if they’ve had any misconceptions.”

Feelings about hands-on science and inquiry.

It is noteworthy that Ashley's approach to science was through hands-on engagements she considers integral to the learning process. Through these hands-on activities, Ashley's students engaged in various authentic science practices, including data collection and analysis, reasoning with evidence, and constructing explanations for different phenomena. While hands-on activities alone do not necessarily indicate an inquiry learning environment, the manner in which Ashley engaged them and the goals behind the use of hands-on activities reflected an inquiry approach. Ashley's students did not engage in hands-on activities with the purpose of verifying information she had told them or that they had read about upfront. Rather, the purpose of the hands-on experiences varied depending on the nature of the phenomenon being studied. For example, when conducting observations of different seeds, her students were recognizing that seeds from different plants, while all part of the same stage of a plant's life cycle, all look different. This information would be further explored later when they eventually planted the seeds they selected and conducted observations of these different plants as they grew. In the case of the white light investigation, even though Ashley started with the stated goal that her students "understand that white light is made of different colors," the purpose of the hands-on learning was to serve as an exploration of a hitherto unknown phenomenon that would serve as foundational to later investigations into the nature of light.

Similarly, Miranda described how she had implemented what she learned from her science professional learning experiences by focusing on the phenomenon before presenting informational text sources, such as textbooks, readings, or videos, to the students. She described how during the previous year, she would introduce science

concepts to her students in the form of textbook readings or short videos. During this, key vocabulary and terms were also introduced and defined. This would be followed by an activity or investigation to demonstrate what they had already read about. As a result of more recent professional learning, however, she now focused on the phenomenon or investigation first, allowing her students to attempt to explain or figure it out in their own words. For example, in describing a lesson on day and night in astronomy, “instead of saying ‘Okay, now we are going to talk about day and night, let’s look and figure out how day and night works’. Not saying that and letting them figure that out first, I’ve done a lot more of that this year than last year.” She explained how she had “tried to incorporate a lot more inquiry, hands-on, ‘let’s try to figure it out first then put a name to it’ ... so that they have those experiences that they can pull from later. And then, after we’ve done something, then going and putting a name to it and digging deeper into what that actually was that we figured out in this different investigation.” In elaborating on what she meant by “inquiry,” she explained “starting with the problem or an investigation... and then figure out why that happens the way it does and then putting the science behind it, reading about it, or watching a video or something to pull in the vocabulary.” As a results, Miranda felt that students best learn science when it was through what she described as an inquiry approach, focusing on the learning experience, investigating a phenomenon, or “giving them a problem and you tell me what’s happening, or what do you think is happening” before using books, videos, and other resources. She felt that “they are able to pull back from those experiences more than classes in previous years.” In comparing her current approach with the way she taught science previously, she felt that in both cases her students enjoyed learning science. She

described how previously, when she taught science with the content and vocabulary focus up front, her students “may have seemed like, when we were doing the investigations, it seemed like they knew what they were talking about because we had already read about it, watched a video, done whatever. So it appeared when they were actually doing the investigation that they understood it better.” In contrast, she described how with her current students engaging in the experience or investigation at the beginning of the learning, “they are like, ‘oh that’s what that was when the water was collecting on the side of the bottle’” after they were finally introduced to the vocabulary that connects with the phenomenon they had previously observed. As a result, she felt like “they enjoy it now being able to figure it out on their own, rather than me telling them and them doing it.” In this way, Miranda described her role as “facilitating, not like, not preaching to them or telling them this is the right answer and this is why it happens, but kinda facilitating them in that investigation towards figuring it out.”

In describing how she approached teaching science, Tali said that she started by “looking at that standard and figuring out what standard is asking of us... and once we formulate our big question, or what we want to know, giving them a hands-on activity.” She explained that she does this because it made the science concepts more meaningful for her students if they engaged in the phenomenon first and then related the vocabulary and concepts through the use of textbooks, videos, or readings back to the hands-on experience. In elaborating on why she most often put the hands-on experience before the textbook readings, she explained how “if they’ve read about it it’s not as meaningful as if they have the hands-on first.” Like Ashley and Miranda, Tali also felt that students best learn science when they were able to engage in hands on activities that allowed them to

build an understanding of the concept of phenomenon they are learning about. “Being able to do things to build that understanding.” She explained this through a metaphor about learning to ride a bike, describing how “you can watch somebody but until you do it you don’t really learn.”

Feelings about student connections with science.

Ashley looked for opportunities “to help them make connections in their everyday life” with the science she teaches. This often took the form of stories, both her own and those her students shared, that made the science they were currently learning relatable and personally relevant to their lives. She also pointed out connections the students could make between the experiences and examples in class with things that might experience or find around their homes.

Miranda also helped her students make connections with the science she was teaching and their everyday lives as a way to help them engage with the science they were learning. She felt that her use of authentic, experiential learning helped all of her students become connected to what she was teaching. By making it authentic, she felt that she was able to help them see that “science is all around them, even though they might not realize it.” She also described how in cases, such as revolution in astronomy, it helped to give them “different types of experiences,” especially with abstract concepts, that would give her students lots of different ways to help them make sense of the concepts. In explaining how these experiences have influenced her teaching, she described how she had implemented what she learned from her science professional learning experiences by focusing on the phenomenon before presenting informational text sources, such as textbooks, readings, or videos, to the students. She described how during the previous

year, she would introduce science concepts to her students in the form of textbook readings or short videos. During this, key vocabulary and terms were also introduced and defined. This would be followed by an activity or investigation to demonstrate what they had already read about. As a result of more recent professional learning, however, she now focused on the phenomenon or investigation first, allowing her students to attempt to explain or figure it out in their own words. For example, in describing a lesson on day and night in astronomy, “instead of saying ‘Okay, now we are going to talk about day and night, let’s look and figure out how day and night works’. Not saying that and letting them figure that out first, I’ve done a lot more of that this year than last year.”

Feelings about the teacher’s role in the science classroom.

Ashley felt her role “is to help inspire, ignite their brains to not have limited opportunities... to have them look at science and not have a fear of it.” Ashley described herself as an “energetic” teacher, something she said has been part of her efforts to overcome her fear of teaching science, “excited and exciting,” and one who anticipated and became excited about how her students would react to what she was planning for them. In describing the teacher’s role in the science classroom, Tali explained that she feels her place was to be a facilitator of learning, whose responsibility was to provide experiences for students to engage in and understand before providing more concrete notes and direction instruction, scaffolding “them through a way of thinking to connect with what they should actually know,” having them make those connections as opposed to her pointing the connections out for them. Miranda also held a similar feeling about the teacher’s role as a facilitator and not to be “preachy” about science.

Perceived weaknesses with regard to teaching science.

In describing her weaknesses when it comes to teaching science, Ashley described struggling with bringing structure and coherence to her science teaching to make her lessons seem less like a series of disjointed, strung together activities, and more like an ongoing narrative of experiences that are helping her students work towards certain overarching learning goals.

In reflecting on her weaknesses, Miranda described how for her “it goes back to knowing everything and why everything happens the way it... just knowing all the content. It’s just hard.” As evidence of this, she described how she had “a lot of really smart kids in my room and they ask some really hard questions,” which forces her to feel like she needs to be “prepared for anything they might throw at you.”

In reflecting on her ongoing weaknesses, Tali said she is looking for ways of “helping them make the connections between what we did hands-on and what the standard are aligned to.” She also said that working on “using that vocabulary all the time with them to help them understand” is a weakness she is working on. However, when she began to critically analyze her own practices, she noticed that she was not modeling the use of the very same content-specific vocabulary during instruction that she observed lacking in her students, for example, using the phrase “the light is bouncing back” in describing an observation in class but asking them to explain “reflection” on the assessment without having ever introduced or modeled that term with the class. As a result, she had made an intentional effort to not only model the use of the terms she wanted her students to become familiar with, but also to communicate and support her expectations for her students to use science-rich vocabulary. She also described her plans

to add “a word-wall for science so that I can focus on those and those words are not foreign to them.” This focus on vocabulary accounts for why Tali made the use of science-specific terms such a priority in her class, as evidenced in her observed lessons.

Tali described one of her main challenges in teaching science as addressing student “misconceptions that they come with or the beliefs of science that they come with” about natural phenomena. As an example, she described how some of her students held deeply entrenched beliefs regarding supernatural or religious perspectives on why it rains. At the same time, she noted that it was important that she addressed these misconceptions in a way that was not disrespectful, for example by simply “telling them that they’re beliefs aren’t real.”

Perceptions and attitudes towards students.

Ashley felt her students have come to “love science” through how she leveraged their curiosity around the mystery of something or through how she provided hands on experiences for learning. “They love to get their hands dirty... I think that helps them to learn.” She noted that not only would her students talk about science during their lessons, but that they would also come talk with her outside of class, such as during recess, about science. She felt that all her students had the capacity to learn science through the experiences she provided and the exposure to opportunities in learning. “I think all of them are capable of learning science... because of the love of it.” She said, “I wouldn’t surprise me if two or three of them went into science or engineering.” She wanted her students to not be afraid of science the way she once was, especially young ladies who she felt were often told they were not as capable at science as young men were. She wanted her students, especially her female students, to have open minds and see no limits

when it comes to learning science. “I do get on my girls a lot. Sometimes I’ll say ‘Girls, ya’ll know... math and science... a lot of girls shy away from that but there’s nothing to fear’... We need those girls.” “My purpose is really... trying to open up minds where... the sky is not the limit for you. It’s wide open to you. You can do whatever you want to do in science.” Ashley believed in her students, in their ability to learn science, and in their capacity to not only work as scientists, but for some of them to one day have careers in math and science.

When considering her students and their ability to learn science, Miranda communicated that she felt that “they are very capable” of learning science, although for some it does come more easily. She noted that as a result of her school being involved in the cluster grouping program, she had a wide range of abilities represented in her class. Still, she felt that all of her students can be successful in learning science because she had created “safe classroom environment where they’re able to throw out their ideas and if it’s wrong, it’s okay but we’ll figure out what it is.” As a result, she felt that she had provided a setting that helped build their confidence and made it “comfortable... to say what they are thinking and ask any question that they have and that helps them understand.”

Tali explained how the science PD she had received also “makes me raise my expectations for my kids as far as science and the answers that they give... instead of saying ‘Hey, is this correct,’ with a drawing that was incorrect, I put it (a drawing of a prism) on the board and say ‘how can we fix this, what is wrong with this’... Making my kids explain their thinking and seeing themselves as scientists.” Beyond just finding out if the students know some fact or detail about science, her focus had shifted to pushing her

students to explain their thinking and reasoning behind their explanations. She also worked to get her students to see themselves as scientists. Tali explained that she thought “that they’re all capable of learning science,” based on her conversations with them, especially in their ability to make connections to what they have learned in previous grades, as well as their standardized test scores.

Feelings about the community served by their schools.

Ashley described her students at Pinnacle Elementary School and the community that school served as “poverty stricken.” She explained, however, that her students were emotional and “very caring,” “supporting,” and “loving.” Ashley felt that the families of her students placed a great deal of trust in her and, consequently, showed support both for her as well as support for their children’s learning. “I think I have their support. They trust me. They know I love them.” She has heard them say with regard to what her students are learning in science “We didn’t learn all of this... you know... when I was in school” both in terms of the concepts they were learning as well as the hands-on manner in which they were learning through inquiry. “Their support is that they trust me and they know I love their students and I want what’s best for them.” Ashley recognized that many of her students came from a background where they have had limited life experiences, but also a culture in which she felt trusted as their teacher by the community members she served.

In describing the community Normandy Elementary Schools serve, Miranda noted that hers is a Title 1 school with approximately 70% of the school’s population qualifying for the NSLP, where “most of the students at this school are of a lower socioeconomic background.” She noted, however, that this is not always the case with her

class; “the breakdown, socioeconomically, is a lot higher this year. And it just depends on the kids. Last year it was a lot lower. My first year it was a lot lower.” Miranda did not feel that the parents of her students were very supportive of what she did in teaching science. She felt that the parents view teaching as her job and, as a result, were not very involved with her class.

Tali described the community served by Grissom Elementary School as a “very supportive community in terms of needing things, needing supplies, needing people to come into the school and either do demonstrations or talk to our class.” She also explained how the parents of her students and other community members would “volunteer if need be.” She also said that she does not feel like they (the school) “do a lot with the community but the community does a lot for us.” She went on to explain how this extended specifically to the parents of her students. She talked about how she sent home a weekly overview of what the students were learning, encouraging the parents to ask their children about what they were learning. As incentive, she said that if the parents emailed her about these conversations, the students would earn bonus points on their grade. She reported that she gets a good response rate from her families. When comparing her current experiences with the school she previously taught at, she explained that she felt there was not a strong connection between “the school and the community itself.”

Engaging low SES students.

When describing the challenges she felt she faced as an elementary science teacher in a school supporting a low SES community, Ashley cited the limited experiences of her students as one of the main struggles as it meant she needed to work

that much harder to provide experiences that she felt they may not receive if not for her efforts. She described one such recent experience where her students recently had the opportunity to visit a local planetarium. “It’s amazing. We went to the planetarium on Tuesday and it was just amazing. It was like ‘whoa’. They saw all the constellations and all that and it was just amazing to them. They haven’t been exposed to that.” This desire to help provide meaningful experiences was also part of her reason for engaging her students in small-group learning where they not only work on the science, but also work on developing and practicing life skills. “I know I’m teaching 4th graders but at the same time I am trying to put in some life skills there.” She noted that she often saw her students supporting one another in these groups. Vocabulary was another area where she felt the challenge of teaching science to her students, a feeling that was largely responsible for her deliberate focus on having her students talk and work “as a scientist.”

In order to engage all of her students in learning science, Miranda tried to make “sure all their voices are heard,” describing how she worked hard at the start of the school year to create “a positive classroom community” that would feel safe and where her students would be willing to engage and share in the learning experience. She also described how she would often walk around the classroom to ensure that all of the students were actively engaged in the lessons, including who she described as the students who “don’t want their voices heard” and who are often less inclined to take an active role in classroom discussions. She also used their responses to her exit slips and online polls to help her identify engagement based on how well the students were able to communicate their understanding, as well as provide a degree of anonymity in sharing what they’ve learned.

Miranda also explained how she used the investigations and problems that were part of her inquiry-focused teaching as a way to help her students make connections between what they were able to experience first-hand with broader, more abstract science concepts. She felt that this not only helped them better understand a concept, but also helped them build their own confidence as learners by providing a safe learning space.

Tali worked to engage all of her learners and make science meaningful and personally relevant by trying to help them make meaningful connections “to things they are interested in,” such as racing video games, as well as “things that they see on a daily basis.” In making sure all of their voices are represented, Tali described how when she had her students work in collaborative groups, she encouraged her students to “share out so that I can hear everyone’s idea from the group.” Additionally, she invited her students to indicate whether or not they agreed with another classmate’s explanation or answer, but she also expected them to explain why they agreed or disagreed.

Differentiating instruction.

Ashley described differentiating for her students through her use of stations where she was able to provide students with different types of learning experiences all focused around a common theme. She also explained how she differentiated through different reading levels and modified her assessments to best meet her students’ needs and readiness levels. Most significantly, she felt that the way she used questions to engage her students in discussion differentiated the learning for her students because she was able to personalize how she interacted with each student as an individual.

In meeting the needs of her diverse class population, Miranda employed a self-paced learning resource she called a science playlist. She described this as an adaptation

of something she and her fellow teachers used for workshop in ELA and math, where students would have a menu of possible activities and engagements they could explore at their own pace as a way to extend beyond the more structured, whole class learning experiences. She described this playlist as “self-paced learning” in which her students would “have time to work at their own pace on stuff to supplement my lesson.” The items on the playlist could include games, interactive online resources, videos, writing prompts, etc... and would all relate to the overarching concepts in current the science unit. In describing how some of her learners would move through their work quickly, while some would take more time, she explained that the playlist was a way to give her students choice in their work but still keep them engaged in active learning, recognizing that “what I was doing wasn’t going to work for everyone.” Additionally, “while they’re working on the playlist, I’ll pull a small group of students in order to go back over something we’ve already done and do it in a different way. Because if they didn’t understand it the first time, doing the same thing over again isn’t going to help them. So, trying to pull in, trying to figure something else I can do, another way to show them whatever science concept it is to help them better understand it.” Miranda also noted that this helped when some students get lost in the crowd.

With regard to differentiating instruction, Tali described how she used the text in alignment with the reading levels of her students. She also used scaffolded note-taking techniques based on her students’ abilities.

Influences and experiences that impact teaching diverse students.

While she had received training from her school district’s Chief Diversity and Multicultural Inclusion Officer, Ashley explained that much of her learning about

meeting the needs of diverse student populations was largely self-initiated, motivated out of a desire to provide the best learning experience for her students. Ashley focused on providing hands on experiences, recognizing that students from disadvantaged backgrounds often lack the opportunities and experiences of their more privileged counterparts.

While Miranda felt that most of her college coursework did not prepare her for her day to day work, her college courses related to diversity “opened my eyes to what else is out there that maybe I didn’t actually realize.” She explained that this was impactful as she came from a town in the state that she described as not being very diverse. She also described professional learning she had received since joining Normandy Elementary School as part of addressing the needs of gifted and talented students through a cluster grouping program the school was a part of. She described professional learning for teaching gifted and talented students as “interesting to see how you differentiate between those kids and how you need to differentiate to meet their needs,” also recognizing that “every child is different and no child is the same. So you have to tailor your instruction in order to meet those needs.” As a result of this, Miranda recognized that many of her students have “very interesting, different home lives.” She related how recently she learned that many of her students have never left their local community and have not had the range of experiences that she has had. As a result, she worked “to bring in those experiences that maybe they’ve never had before in order for them make connections.”

Although Tali had not received an abundance of PD on teaching diverse student populations, what she did receive came from her current school district and focused on

identifying her own cultural biases and how they might influence her interactions with her students. She went on to explain how as a result of that training, she had become more aware of her own biases regarding her expectations for her students. She described how this training caused her to recognize her own bias with regard to her perceptions of what she thinks her students can do, explaining how “when I walk in the class, I’m like ‘your scores are here, you should be able to do this’... these kids can do this, and these other kids can do this. So, I already came in knowing what I think they should do, ‘you should know how to do this, or you can’t do this’ and then not giving them the opportunity to either excel or show me that they can do more or giving them the tools they need to grow because I think they should have already known how to do that.” A key element of engaging learners from various back grounds is first recognizing the cultural differences between the students and the teacher, including those that inform biases. Being aware of one’s personal biases is a crucial step in recognizing that one’s students come with their own different perspective of learning, informed by their own cultures, life experiences, and values (Grimberg & Gummer, 2013; Laughter & Adams, 2012; Lee, 2004; NRC, 2012).

Memorable experiences teaching science.

It is not surprising that Ashley described one of her most memorable experiences teaching science as one in which she credited her students for such an experience. She went on to explain how this experience was one that pushed her to be a better teacher because she had a group of students that she felt connected with.

“Because with organisms... we had a chance to really really dive into the standards and really just open up all of the experiences with them with the plants,

with the bugs and the seeds. And it was just... with this group, it was just... because this was the first year I taught it to this level... this level of teaching... as far as going that... this class was so hands on... but this group pulled more out of me as a teacher.”

She felt this is because she had taken the initiative to dive into the standards and provide “lots of experiments” for her students. “That’s why this was one of the most memorable experiences for me.” For Ashley, being a science teacher was about making sure her students developed a love for science that she, herself, did not experience as a young student. It was about enabling her students to be the successful young scientists she believed they could be. And it was about how her students, in turn, made her a better teacher.

Despite astronomy being one of the more challenging and abstract units for her students, she described one particular experience from the current year’s astronomy lessons that was particularly positive for her. When doing a ‘planet walk’ activity about the solar system, Miranda described how, instead of just reading or watching videos about the planets, her students picked different planets, researched, and created models of their planet. They then put them in a mock museum display and shared their learning through presentations. Finally, they did the ‘planet walk’ where they spaced their planets out in a scaled distance model of the solar system. Miranda described how her students “had a lot of fun doing it” and were amazed by the relative sizes of and distances between the planets. Overall, Miranda “really likes teaching science.” In describing one of her more positive teaching experiences, Miranda related how through the design of her learning, around choice and modeling, her students not only enjoyed the learning

experience, but also how their understanding of abstract ideas and concepts grew in ways that amazed them.

One of Tali's most memorable experiences teaching science was when she recently taught the phases of the Moon. She described how her students initially had a hard time recognizing that there is a predictable pattern to the Moon's appearance, that they did not "make a connection that the Moon does not change randomly." Through the use of student-collected observations as well as modeling the Phases of the Moon in class, her students "were able to go around and see the Moon changing and the different phases." came to recognize the patterns in the phenomenon. What made this particularly meaningful for her was that it was one of the first times her students "made a connection to something I've asked them to do out of school with what they're doing in school." She described how finally "it clicked" for them. It had such a profound effect on Tali that she described it as helping her realize that "this way of teaching science was something I would like to continue."

All three teachers share a similar story about how they were initially apprehensive about teaching science, stemming primarily from limited background and personal experiences with science and science inquiry. However, despite this apprehension, all three described how they enjoy teaching science and how they felt their students enjoyed learning science with them. The three teachers also described receiving positive professional learning from their school district in support of teaching science and that this PD had an impact on the way they taught science, in particular how they taught with a focus on understanding and sense-making by engaging with scientific phenomena through hands-on learning experiences. While feelings of apprehension towards science

along with limited experiences with science inquiry or science concepts is typical of elementary teachers (Akerson, et. al., 2009; Mensah, 2010; Sherman & MacDonald, 2008; Slavin, Lake, Hanley, and Thurston, 2014), it is atypical for elementary teachers who have suffered from this lack of experience or science content background knowledge to express very positive attitudes about their feelings regarding teaching science. Similarly, it is not the norm for elementary teachers to describe having positive, impactful science PD (Adamson, Santau and Lee, 2012; Johnson & Fargo, 2014; Thomson & Kaufmann, 2013).

Ashley, Miranda, and Tali all shared similar ideas in terms of how they felt students best learn science, primarily through hands-on experiences with different phenomena with a focus on sense-making and understanding. They felt that these hands-on experiences should precede any direct instruction or explanations on the part of the teacher or through the use of informational text resources. These teachers also felt that discussion was an important element of this sense-making learning process and they used questions not only to assess the degree of understanding and possible misconceptions, but also to foster discussions in their classrooms. Their beliefs regarding how students best learn science also informed the role they each felt the teacher plays in this process, that of facilitator as opposed to the knowledge authority in the science learning experience.

For all three teachers, vocabulary was important, though not in the sense of memorizing terms or definitions. Rather, they felt that it was important that their students saw themselves in the role of scientists, including through the intentional use of science-specific vocabulary during their discussions and writings. This focus on the importance of accurately employing science vocabulary helped students feel that they were a part of

the science learning community by establishing and supporting a common language and dialogue (Townsend, Brock, & Morrison, 2018). The teachers also felt it was important that their students were able to make connections between the science they are learning and things they experienced in their every-day lives around them; therefore, they each made an explicit effort to include and illustrate these connections for their students. A focus on understanding and authenticity over memorization, as well as an emphasis on the use of hands-on science to develop that understanding is also not typical of many elementary science teachers whose lack of experience or support for teaching hands-on, inquiry-focused science often results in science being taught as either a series of meaningless hands-on activities or through a didactic approach to teaching science (Diaconu, Radigan, Suskavcevic, & Nichol, 2012).

Despite the positive beliefs and attitudes expressed by the three teachers, they each indicated an area of weakness that they continue to struggle with. For Ashley, she struggled to bring coherence and strike a common purpose among the different science lessons and hands-on experiences she provides for her students. For Miranda, she felt that her lack of science content knowledge was a challenge, especially when her students came to her with complex and abstract questions or ideas. And for Tali, she struggled to help her students see the connection between their hands-on experiences and the overarching science concepts as communicated by her state science performance indicators and standards.

In addition to describing their feelings that their students mainly enjoyed learning science from them, they also shared a common belief that their students were capable of learning and being successful at science. As noted previously, this belief in the capacity

for their students to be successful is a chief characteristic of CRP (Ladson-Billings, 1995; Laughter & Adams, 2012; Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995). The teachers also expressed a belief in the importance of student voice in the learning experience, as well as the need to differentiate the learning experience based on the diverse needs of their learners, another quality of CRP (Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995).

Two of the teachers, Ashley and Miranda, described their perceptions of the students they serve as coming from communities afflicted by poverty that had the result of their students coming to school with limited life experiences or robust science knowledge backgrounds. In describing their perceptions, they also explained how they felt the need to provide connections and experiences that their students might otherwise not have the opportunity to engage in or have been exposed to in the past. Both Ashley and Tali described having positive interactions with the parents of their students, with Tali describing how she made a proactive effort to foster family involvement in the science learning experiences of the students. In contrast, Miranda described how she felt that the parents of her students regarded it as her job to teach their children and, subsequently, did not demonstrate a willingness to be actively involved in how the students learned science. Recognizing the diversity of and barriers to success between different communities and the school setting is an important element of CRP ((Gao & Wang, 2016; Grimberg & Gummer, 2013; Ladson-Billings, 1995; Phelan, Davidson, & Cao, 1991), as is fostering connections and involvement between school and community (Brown & Crippen, 2016; Grimberg & Gummer, 2013; Ladson-Billings, 1995; Powell, Cantrell, Malo-Juvera, & Correll, 2016). It is noteworthy that these last two

characteristics were not shared by all three participants, though their absences from among the attitudes and beliefs of the respective participants did not seem to significantly impact the success of their students. It is also noteworthy that none of the teachers included elements of social justice or community advocacy as part of their science teaching even though this is often cited as a common element of CRP and culturally responsive teaching (Brown & Crippen, 2016; Laughter & Adams, 2012; Powell, Cantrell, Malo-Juvera, & Correll, 2016).

ANALYSIS OF STUDENT PERSPECTIVES

Participant 1: Ashley.

To gain insight into impact of Ashley's approach to teaching science on her students, six members of the target class participated in a semi-structured focus group interview. These students were selected by Ashley and represent what she feels is a representative cross section of her class. For the purposes of analyzing their responses, they are identified in the following manner:

- Student A: African American male
- Student B: Hispanic female
- Student C: African American male
- Student D: Caucasian female
- Student E: African American female
- Student F: African American male

Note that the identification of the focus group students as Student A through F is independent of the similar terminology used to describe interactions taking place during the observations.

In general, Ashley's students described enjoying learning science from her and were enthusiastic in their descriptions of what they appreciated about how she taught science. In addition to describing her in terms of being "a great teacher" who "teaches science nice," Ashley's students not only described specific elements that they appreciated, but also noted how many of these elements helped them to understand science concepts. Student D noted how Ashley "explains things" while Student F described how she "lets us ask a lot of questions." Student E added that Ashley taught science in a way that helped them "to better understand," explaining that "she draws a diagram, or she draws something else so we can understand it better." Student A also focused on the idea of understanding, noting that Ashley "teaches it in a certain way so we can understand." Student F also described ways that Ashley helped them with understanding, explaining that she "always explains and if we were to not understand, she will take a whole class to do a lesson."

Ashley's students also described things that she does that help them engage with the learning, from telling "interesting facts" to how "she likes to give us examples, like pictures and stuff." Student D noted that she "loves to do experiments and test things." Several of Ashley's students also remarked on how they enjoyed her sense of humor, with Student F explaining that there was "always a funny comment" that he enjoyed. Ashley's focus on hands-on learning was also evident in how Student A described how he liked "feeling and touching stuff." Student B added that Ashley "shares good stuff, interesting stuff about science with us."

In describing what they liked about Ashley as their teacher, Student E noted that "she's funny and she is nice and she is careful about every other student in 4th grade,"

explaining that she felt that Ashley cared about all of the students in 4th grade.

Additionally, Student C related how Ashley talked about her son to the class.

All of Ashley's students agreed that they felt that she believes in them and that she believe they can be successful in science. Student C noted how Ashley "pushes me to be a hard worker and stuff" and that he loves the "way she thinks about me and stuff." Student A agreed that he liked the way Ashley "pushes us to keep trying." Student A also related how "she knows we can do good in science and she knows we can be great." Student B said, "she teaches extra things to learn more and pass on tests." Student C explained how "she tries to put that much pressure on me sometimes... but helps me learn better sometimes." Student D said, "she gives us, like, confidence" while Student E noted that she "pushes us to the limit." Even when being strict, Student F noted that "when she says something mean... she doesn't really mean it. it's always to push us." Student A added that "you have to have confidence in yourself... She cares about our work as much as we do... She has confidence in us and she's putting in effort to boost our confidence."

Also, Ashley's students all said they felt like they were all a part of the classroom community when it came to learning science. Student E said "they (her classmates) understand the way I know how to learn science." Student B reflected back on her feelings about Ms. Ashley, saying "she pushes us in the classroom, she believes in us." Student C noted that "my class cares about me... They all help me. They never leave me out." Student A' feelings about the community include feeling good "when we do something, and everyone understands it." Student D noted that when working in groups, "sometimes, like when we get in groups, the group always like lets you explain and lets

you think about your thoughts, and like help you with your questions and answers.”

Student F followed up by saying that “when we get into group, we’re all looking out for each other.”

In reflecting what they did not like about learning science in Ashley’s class, her student shared that they did not like how she had to address disruptive students. Although this was initially discussed as something they did not like about science, their responses indicated that they recognized what they did not like was how these disruptions made it hard for them to engage in learning science. Student E explained that “they’re blocking us from learning.” Student C noted how when addressing this behavior, Ashley would sometimes address the disruptive student by saying “you can teach yourself” and gave the student a chance to step up and teach the class instead, with Student E added that these students acted like “they already know the lesson.” Student F elaborated on this, explaining “she’s like ‘if you’re not going to pay attention and you’re just gonna talk to other people, okay then, go up to the board because apparently you already know this’.”

This disdain for disruptive student behavior also came up when asked what they would improve about learning science in Ashley’s class, with Student A explaining that this kind of behavior got “in the way of learning.” Apart from that, most of their responses focused on wanting to do more fun things in science, with Student C explaining that he would “make it more fun... I want kids to learn new lessons about science in a fun way” Student E added that she would “change the way people think about science because they think it’s boring but it’s actually kinda fun.”

It is evident from their responses that Ashley’s students not only enjoyed learning science, but also recognized how their teacher did certain things to make learning

engaging for them as well as to help them connect with the learning to help them understand. It is noteworthy that her students explained the importance of not only learning science facts but of understand what they are learning, as this is consistent with Ashley's own views on how she wanted her students to understand and connect with the science she was teaching. It is also noteworthy that her students recognized that one of the barriers to learning science was not the difficulty of the content or the way Ashley taught it; rather it was the disruptive behavior of some of their classmates that got in the way of learning. Most significantly, all of her students expressed recognition of the fact that Ashley cared for them as learners and that they felt confidence and that they could be successful in science because of the things that she did.

Participant 2: Miranda.

To gain insight into impact of Miranda's approach to teaching science on her students, five members of the target class participated in a semi-structured focus group interview. These students were selected by Miranda and represent what she feels is a representative cross section of her class. For the purposes of analyzing their responses, they are identified in the following manner:

- Student A: African American/Caucasian female
- Student B: African American female
- Student C: female (student did not offer to describe her ethnicity)
- Student D: Indian/African/Spanish female
- Student E: African American/Korean male

Note that the identification of the focus group students as Student A through E is independent of the similar terminology used to describe interactions taking place during the observations.

In general, Miranda's students enjoyed learning science with her and liked her as their teacher. Her students described how she taught science "pretty" or "very" good, though what qualified these generalizations varied among the students. Student E explained that "she doesn't make it boring. It's fun because we do experiments a lot of times," adding that science was his favorite subject because of the content they got to learn about. Student D explained that she liked it "because she gives examples on what it is and she makes the examples because she wants us to see it... for us to understand it better." Similarly, Student A explained how Miranda used examples and "gives us important information that we need to learn and... she gives us examples and she explains it how it goes." Student B also focused on this idea of understanding. "She's making it easy so we can get our grades right and so we can understand it more instead of doing it the hard way." She went on to describe how Miranda's use of "different strategies for us to learn it or how to learn it so it really helps."

The students also described the different things they enjoyed about how Miranda teaches science, most notably the fun they had doing experiments. Student E also talked about how he enjoyed "how she does experiments and stuff. She teaches us what it's all about." Agreeing, Student D described how "it's fun and exciting to do some experiments and projects because you still learn, and you get the fun out of it while doing the experiments and projects." Student A also described how she loved learning about the weather, adding that it is "fun to see how the Earth works and it's fun to see what light is

actually made of.” Student B also explained that she not only enjoyed the way she was learning, but also the things she was learning about.

All five students enthusiastically agreed that they felt that Miranda believes they can all learn science. Student A explained that the reason she felt this way was that Miranda “tries to help me. It makes me think... it makes me feel good about myself.” Student B said she felt this way because “she does different strategies for us to learn it. And if we don’t get that right there, you can come to me... and I’ll explain it more and more.” When asked, she listed how Miranda used pictures, drawings, interactive whiteboards, vocabulary definitions, textbooks, laptop computers, etc... Student D described how Miranda was “very helpful when mostly everyone is having trouble with something that could be hard. She understands that sometimes it’s hard to understand.” Student E said that “she believes in us. She makes things hard kind of... because she wants to challenge us to see how far we can go.” Additionally, Student E explained that “she seems like a good teacher. She teaches us so much that she cares about how our tests are and how we are when we grow up.” Student B agreed by stating “She cares about us.” Student A felt that Miranda “supports me” in helping her connect with the science she was teaching, declaring “I think I can go to college.” Student B explained that “she is always there for us, she’s always cheering, she always cares about us. She’s like our school mom,” not just in science. Student E described how Miranda “has the ‘you can’ attitude” and how he felt that “all the time when we struggle during certain subjects, she’s always there to help us.”

Interestingly, despite the very positive attitudes her students described with regard to their feelings about Miranda, the way she taught, and how they all felt she believed in

them and instilled them with a sense of confidence, their perceptions regarding feeling like they are part of the overall classroom community varied. Student E said he felt like a part of the community because when he raised his hand, “that makes me feel like I am a part of the class... she normally calls on you and you tell her what your question or concern is and then so when you tell her that means that she’s taking it in.”

In contrast. Both Student A and Student B said they sometimes did not feel like they are a part of the class community. Student B explained how “I don’t feel like I’m really welcomed in the classroom... when I tried to help them (a student who needed help), the teacher gets mad at me. I wanted to help her because she wasn’t in the classroom at the time.” Student A described how “nobody barely try to be my partner.” She also explained how “sometimes I get really frustrated... I kinda start to crying... not because we’re sad but because you can’t control your emotional feelings when it comes out.” Student C, in explaining how sometimes she does and sometimes she doesn’t feel like part of the community, described how “we sometimes work by ourselves and sometimes we work with partners.” Student D expressed a similar sentiment, explaining how “I sometimes work independently, I kinda feel the same way I do with partners” though she was quick to add that “I feel confident when I’m doing my work.”

Despite the mainly positive attitudes her students conveyed about Miranda and her teaching, some of her students shared different things they did not like. Both Student A and Student B described how they got frustrated with some of the lengthy examples and writing assignments Miranda gives them. Student D described how she did not enjoy how “sometimes we do projects and people just argue when they are trying to take the fun out of the project,” though this seemed to be more of a reflection of her frustration

with her classmates than about the way Miranda taught science. Student A then added that she also got frustrated with how sometimes “everybody keeps on raising their hands, and we can’t get to something we are trying to learn.” Student E, however, noted that he did not have any problem at all with science, in particular noting that he “thinks it’s good to raise your hands to ask questions.”

This frustration with the behavior of their classmates was a theme that others picked up on. Student D said she would change “all the arguments and the fighting in class,” Student B agreed, saying the arguments were “interfering with your education. And if you can’t learn, you’re not really going to grow up strong and hoping you get a scholarship and college.” Student A followed by saying “you can’t get nowhere in life if you keep on arguing with other people.” Student A also said that she did not like “having to do so much work.” Student E, in contrast, said he enjoyed the work and would like more work.

Despite a few feeling that they were disconnected at times from the class community, Miranda’s students described positive feeling and perceptions about the way she taught science, especially through hands on experiments and relatable examples. Not only did they recognize how she used different strategies to help them connect with the learning, they enjoyed many of the science topics they are learning about. Most significantly, however, is that all of the students felt confidence in their abilities to be successful in science and recognize that is the through the things that Miranda does with them that helps instill this sense of confidence.

Participant 3: Tali.

To gain insight into impact of Tali’s approach to teaching science on her students, six members of the target class participated in a semi-structured focus group interview. These students were selected by Tali and represent what she feels is a representative cross section of her class. For the purposes of analyzing their responses, they are identified in the following manner:

- Student A: African American female
- Student B: African American/Jamaican female
- Student C: African American/Haitian female
- Student D: Hispanic female
- Student E: African American male
- Student F: African American male

Note that the identification of the focus group students as Student A through F is independent of the similar terminology used to describe interactions taking place during the observations.

Tali’s students expressed largely positive feelings about their teacher and learning science in general. In general, three main themes emerged as her students described what they liked about their teacher and the way she taught. Describing how taught science, many of the responses focused on how she made it fun. Student A described how she taught it in a “fun way with different activities for us to learn with.” Student B described how she felt that Tali taught it like “she wants us to be interested in it, and we do fun activities,” noting that she felt this helps them learn. Student C also agreed that Tali taught in a way, “not only telling us stuff, actually letting us do experiments to see how

we think about it.” and that this makes “sure science is fun for us.” Student E also said that the way Tali taught was in a “fun manner but it still helps us learn about the subject she wants us to learn about.”

The second theme that emerged from their responses was that of how the way Tali taught helped them to learn and, more significantly, understand what they were learning. Student A noted that Tali “always makes sure that we really know it.” Student C described how she “always makes sure we some type of reading or text that will help understand better” and that she also checked their notes to make sure they were getting it. Student B enjoyed the experiments and how during their learning they “get to interact with students with what we are doing.” Student A also liked how they got to “work as a group” when they did their hands-on activities. Student C described that she enjoyed how learning through experiments, hands-on, and “different perspectives helped them understand” the science.

The third theme, that of the different things Tali did to make learning science fun and help them understand, was woven through their responses and highlighted many of the particulars they enjoyed, including hands-on learning, experiments, and being able to work in a group.

All of Tali’s students felt that she believed they could be successful in science. They all expressed that one of the main reasons for that was that Tali motivated them to learn science, with Student A adding that “she makes you feel okay.” Both Student A and Student B described ways that Tali helped instill a sense of confidence in them through her use of performance feedback. Student A described how she gave them confidence “when she’s explaining it to us she’s always asking question, like why, and

then she tells you that you are right.” Student B described how Tali made sure “we know what we’re doing and what she’s talking about.” Student C described how when people get stressed, she helped them relax and focus. Student E explained that he felt she believed in them because of how “she asks us why is it important.” Student F explained how “if I don’t understand something, she’ll come back to help me with it and if she didn’t believe in me, that I could be a good scientist, then she probably would have left me where I was at... instead of helping me.” Similarly, Student A talked about how Tali “always helps you with stuff... she went back re-taught the whole lesson to me” when she had missed a class once.

All of Tali’s students felt that they are a part of the classroom community, largely because of the way Tali gave them opportunities and encouraged them to work collaboratively. Student F explained that he felt this way because “because mostly when we learn in science you get to work with your peers around you and they can help you out with stuff.” Student C elaborated by adding that “we always work together in science, well not always but most of the times we work together in science... she comes around helping every group.” Both Student A and Student C described how when they were working in groups, Tali would come around to ask them “questions to make sure we understand” and if they didn’t understand, “she gives us more information about it so that we will understand it better.”

Student A and Student B both said that one of the ways Tali helped them connect with the science they are learning was by how she directly taught them about why it was important to learn the concepts, with Student A noting how “she always gives us life examples of how we can use this in our life and how important it is to know this.”

Student C talked about how Tali “usually tells me a lot about how science can help you in your life,” as well as letting her know about experiments she could do on her own at home. Student F talked about how when Tali assigned reading sometimes “she’ll read something that the article says and it will be something you can use in the world... like if you have a pet or something and it shows what it’s allergic to and Tali explains it and you’ll understand it more.” Student A also added that when there are no pictures in a reading, “Tali will draw the pictures out to show us what it looks like.”

Conversely, all of the students also shared something they did not enjoy about their class. Student A described how sometimes “she actually rushes with the notes,” though they noted that Tali does come back to help them review their notes. Student B and Student C both described how they did not like some of the articles they had to read, especially when they received grades for answers to the questions related to the articles. Student F also talked about not liking the articles, especially when the “articles are really long” but feeling like there was not enough time to get through reading it. Student D felt like “sometimes we don’t have a lot of time for science.” while Student A added that sometimes the experiments were hard to understand.

Both Student A and Student D said that the one thing they would change about their science class would be to have more time to for their science lessons, noting that the time they get for science is usually short. Student C added that she would like “more hands on activities” while Student B wanted “less reading to do.” Student E said that he liked science just the way it is and would not change a thing because he “just likes the way she does it.”

These frustrations over the lack of time the students have to learn science are noteworthy given that among the three teachers, Tali's mean weekly duration of science instruction was lower than that of Ashley or Tali. Not only has reduced time for science instruction been shown to correlate with lower science achievement (Blank, 2013), it is noteworthy that this suggest it also has the potential to negatively impact student attitudes and feelings about science.

Overall, Tali's students had a very positive attitude about learning science in general and about her in particular. They liked the way she taught through her use of hands-on activities and the way she allowed them work in collaborative groups, describing it a fun. They recognized that this not only helped them to learn the science but also to understand it. Additionally, all of her students felt that she believed in them and that they were supported as part of the science learning community. It is significant that one of the main things her students said they would change about learning science in Tali's class was that they wish they had more time for science.

Significance of student perceptions and feelings.

The growth and enthusiasm exhibited by one's students comes when a teacher has the confidence, support, and pedagogical understanding to provide engaging learning experiences that focus on understanding phenomena and when students make a personal connection between themselves and the culture of science learning that is taking place in the classroom. (Grimberg & Gummer, Gutierrez, 2015; 2013; Lee, 2004; Mensah, 2010). All three teaches described how they felt their students enjoyed learning science from them and how they felt that, through them, their students are able to be successful. The overall significance of such positive perceptions is that when students express positive

attitudes towards what they are learning, in particular because of the positive relationship they have with their teachers, they are more likely to expend effort in learning and are more likely to be successful in their endeavors (Kipkoech, Kindiki, & Tarus, 2011; Roorda, Jak, Zee, Oort, & Koomen, 2017).

It is worth mentioning, however, that among the representative student groups, some of Miranda's students' feelings about the degree to which they felt like they were a part of a positive learning community are best described as either ambivalent or negative. What makes this noteworthy is that of the three teachers, Miranda described a disconnect between her classroom and the parents of her students. Despite these feelings, Miranda's students were largely positive about their teacher and their experiences learning science in her class.

ANALYSIS OF MISSING ELEMENTS.

While Ashley, Miranda, and Tali exemplified many of the characteristics of social constructivist science inquiry teaching and CRP, there were certain qualities that none of the participants displayed. Figure 4.3 illustrates the elements of science inquiry teaching and CRP exhibited by the participating teachers. In Figure 4.3, the elements of for science inquiry and CRP are labeled as being evident (E) or not present (X). Additionally, several of the SEPs are labeled as partial (P) if some but not all of the elements of the practice, as defined by the *Framework for K-12 Science Education* (NRC, 2012), were present in the observation. In these cases, the specific details are described below.

Of the SEPs defined by the *Framework* (NRC, 2012), three of them were missing entirely from both the observations and the attitudes and beliefs of all three teachers.

These were asking questions and defining problems, planning and carrying out

Defining Element	Ashley	Miranda	Tali
Science Inquiry			
SEP- Asking questions and defining problems	X	X	X
SEP- Developing and using models	X	E	P
SEP- Planning and carrying out investigations	X	X	X
SEP- Analyzing and interpreting data	E	E	E
SEP- Using mathematics and computational thinking	X	X	X
SEP- Constructing explanations and designing solutions	P	P	P
SEP- Engaging in argument from evidence	P	P	P
SEP Obtaining, evaluating, and communicating information	P	P	P
Teacher creates a physically and socially science rich environment	E	E	E
Learning through SEPs is social in nature with a focus on sense-making and understanding*	E	E	E
Sequenced to explore and engage in a scientific phenomenon before direct instruction*	E	E	E
Teacher assumes role of facilitator*	E	E	E
CRP			
Student identity and voice is valued	E	E	E
High expectations are communicated and affirmed	E	E	E
Relevant connections between content and students	E	E	E
Connections between classroom and families	E	X	E
Students are given choice in their work	E	E	E
Teachers creates a positive, risk free environment	E	E	E
Elements of social justice and connections to community	X	X	X
Sequenced to explore and engage in a scientific phenomenon before direct instruction*	E	E	E
Learning is social in nature with a focus on sense-making and developing understanding*	E	E	E
Teacher assumes role of facilitator*	E	E	E

E: Element is evident in teacher's practices and/or beliefs and attitudes

X: Element is absent from teacher practices, beliefs, and/or attitudes

P: Evidence indicates a partial SEP as defined by the *Framework for K-12 Science Education* (NRC, 2012)

*: These elements are congruent between science inquiry practices and CRP

Figure 4.3 Exhibited elements of science inquiry and CRP

investigations, and using mathematics and computational thinking. Evidence from the

IPL-S, however, did indicate that on at least some occasions, the students did engage in

some of these practices depending on the teachers. Miranda reported one occasion where her students formulated scientific questions and two occasions where they developed and planned to test a hypothesis. Ashley also reported at least one occasion where her students generated a hypothesis, though she does not indicate whether or not they planned an investigation to test their hypothesis. Both Ashley and Miranda indicated only one occasion where their students manipulated a variable in an experiment. Furthermore, beyond a few occasions during which all three teachers reported that their students displayed data in tables or graphs, there was no evidence from observations that their students engaged in mathematics or computational thinking.

Additionally, several of the elements of specific SEPs were only partially evident for different teachers. For example, while observations of Miranda's class displayed evidence that her students engaged in the practice of developing and using models on different occasions, Tali's class only engaged in the process of using models while Ashley's students did neither. Similarly, while the students of all three teachers engaged in the practice of constructing explanations, they did not design solutions to problems. And while they did obtain and communicate information, with the exception of one reported incidence from Miranda's IPL-S where she cited that her students examined scientific claims made by others, they did not evaluate information. With regard to engaging in argument from evidence, as described earlier, while the students in all three classes often used evidence to support their reasoning and all three teachers indicated activities on the IPL-S where students supported their thinking with evidence, this fell short of engaging in true argumentation among students and groups where claims are made, supported, evaluated and considered in the context of counter claims.

One of the characteristics of CRP that the teachers did not exhibit was related to the element of social justice and advocacy. Teachers who engage in CRP practices can often engage students through making connections between the science they are learning and problems and concerns that are taking place in their community. One way this can be done is to have the learning centered on a problem within the community, such as pollution, health care concerns, impact of poverty and limited resources, and to connect the science concepts the students are learning to how they can use that information to address, raise awareness, propose solutions, or take steps to solve those problems. Making of social justice and advocacy a central theme of the learning is a way to engage the students in the experience by connecting to their values and personal and community cultures (Brown & Crippen, 2016; Laughter & Adams, 2012; Powell, Cantrell, Malo-Juvera, & Correll, 2016). While all three teachers recognized the importance of making connections between the science they were teaching and the lives of their students in a way to make the learning more personal and meaningful, these specific elements of social justice and advocacy were absent from all three teachers' lessons.

As described earlier, it is also noteworthy that of the three teachers, Miranda was the only one who indicated a disconnect between her and the families of her students in how she described the families of her students as regarding the responsibility of teaching to be primarily the role of the teacher and generally not showing a great degree of supportiveness. It was also the some of the students from her class that indicated that they did not always feel like they were members of their classroom community.

CHAPTER 5

DISCUSSION

The phenomenon of the science achievement gap is one that is persistent and problematic (Curran & Kellogg, 2016; Noble, Rosebery, Suarze, Warren, & O'Connor, 2014; Quinn & Cooc, 2015; Vijil, Slate, & Combs, 2012). Students from diverse backgrounds that are often marginalized, be it through the lens of language, ethnicity, gender, or socioeconomic status (SES), routinely manifest an achievement gap when compared to their fellow classmates from more privileged backgrounds. In terms of how a student's SES can impact performance outcomes, the achievement gap can result from many different factors, including poverty-related characteristics of one's environment, limited life experiences, generational poverty, lack of resources, both within and outside of the school setting, and the economic segregation that often impacts the resources schools receive as a result of the reliance on a local tax-funded education system (Crook & Evans, 2014; Dearing et. al., 2016; Hani, 2012; Lee, 2012). In the elementary setting, this is exacerbated for science as a result of persistent challenges related to effective science teaching. Elementary teacher are less likely to have a strong background in science, both with regard to content knowledge (Deniz & Akerson, 2013; Sandholtz & Ringstaff, 2013; Slavin, Lake, Hanley, & Thurston, 2014; Thomson & Kaufmann, 2013) and with regard to an understanding of and experiences with science inquiry teaching (Akerson, et. al., 2009; Ricketts, 2014; Schwarz & Gwekwerere, 2007; Watters &

Diezmann, 2007). When coupled with the systemic barriers to effective science teaching endemic to the elementary setting, often driven by standardized testing that push districts and schools to prioritize English language arts (ELA) and math in terms of allocation of resources, instructional support, funding, professional development (PD), and expectations of time spent teaching different content, science teaching often gets minimally addressed and typically in a superficial manner that emphasizes memorizing facts without context or authentic experience (Blank, 2013; Mensah, 2010; Sandholtz & Ringstaff, 2013; Slavin, Lake, Hanley, & Thurston, 2014). Given the challenges that schools in low SES often face when attempting to recruit and retain quality teachers as well as fund the necessary resources to provide students with a robust learning environment, this makes it all the more difficult for elementary schools serving low SES communities to provide reform-based science inquiry learning experiences for their students (Chudgar & Luschei, 2009; Duke, 2000; Hani, 2012; Whipple, Evans, Barry, & Maxwell, 2010). When these historic challenges to effectively teaching science in the elementary setting are compounded by the barriers to achievement related to students and schools in low SES settings, it is little wonder that the achievement gap in elementary science is so persistent.

Despite these challenges, there are teachers who teach high percentages of low SES students who have shown on the results of state standardized science tests a reduced achievement gap when compared with their higher SES counterparts within the same district. For the target district in a southeastern state, twenty-one 4th and 5th grade teachers met the criteria of teaching in a school that serves a population for whom 50% of more of the 4th and 5th graders qualified for the National School Lunch Program

(NSLP). Additionally, these teachers taught one or more classes in which at least 50% of the students also qualified for the NSLP, both during the 2016-2017 school year from which test scores were analyzed and during the 2017-2018 school year. Finally, the results of the NSLP qualifying students for these twenty-one teachers showed not only that the percentage of students who met or exceeded the expectations on the state's standardized science test outperformed the district's percentage for those same students but also that there was a smaller gap between mean test score for their NSLP qualifying students and mean test scores of the district's students who did not qualify for the NSLP when compared to the district's achievement gap between these two groups of students.

The data regarding the instructional practices, attitudes, beliefs, and student perceptions of three of these teachers were collected through several classroom observations, interviews, student focus groups, and participation in a science instructional practices log. When these data are analyzed, it becomes evident that these three 4th grade teachers exhibit several characteristics that are congruent with several of the defining attributes of both science inquiry teaching and culturally relevant pedagogy (CRP). When teaching science, these teachers engaged their students in sense-making learning experiences through the use and application of authentic science inquiry practices and in a social constructivist environment where students apply authentic skills in the context of real world, familiar scenarios to construct knowledge through social interaction (Braaten & Windschitl, 2011; Cavagnetto, Hand, & Norton-Meier, 2010; Watters & Diezmann, 2007; Windschitl, 2002). Additionally, through their use of positive rituals, communicating high expectations and meaningful affirmations, meaningful and familiar

context, and breaking down the traditional teacher-student power dynamic through giving students voice and assuming the role of facilitator of learning, these teachers created a positive, safe, inclusive culture that invites participation and engagement on the part of all of the students (Brown & Crippen, 2016; Ladson-Billings, 1995; Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995).

Additionally, the attitudes and beliefs of the three teachers indicate that their approach to teaching science is informed by a social constructivist view of teaching science through inquiry practices that focus on sense-making, hands-on activities and student collaboration and discussion. All three teachers indicated that they believe students best learn science through hands-on investigations where students engage in scientific phenomena through explorations, investigations, and simulations, all with the purpose of developing an understanding of the phenomenon (Kim & King, 2012; Passmore, Stewart, & Cartier, 2009; Wu & Hsieh, 2006). For these teachers, this learning process includes students engaging in collaborative work and sense-making discussions, often prompted by questions intended to both foster discussion and provide a means of gauging the development of conceptual understanding (Chin, 2007; Cochran, Reinsvold, & Hess, 2017). These teachers also place an emphasis on the importance of vocabulary, both through how they model the use of science-specific terms as well as how they communicate the expectations of use for those terms (Townsend, Brock, & Morrison, 2018). While these teachers acknowledge that many of their students come from low SES environments, they share a common belief in the ability of their students to be successful in learning science (Brown & Crippen, 2016; Ladson-Billings, 1995; Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995).

The students of these teachers all communicate a very positive attitude both about their teacher and about learning science. They recognize that their teachers each make an explicit effort to help them understand the science they are learning. They describe their respective science experiences, as well as their respective teachers, as being enjoyable and fun. Most significantly, they all report a feeling that they believe their teachers has faith in their capabilities as learners and that she actively works to help all of their classmates be successful in science.

CONCLUSION

The driving goal of this study was to identify the characteristics, both in terms of practices and attitudes, of teachers who have shown some measure of success in helping their low SES students reduce the achievement gap with regard to elementary science. Driven by a theoretical framework that posited the potential influence of both science inquiry practices, particularly those aligned with a social constructivist approach to learning, and CRP, this study sought to find out if these teachers exhibit the characteristics of either or both of these influences. Driven by this framework, the following research questions defined the nature of this investigation:

- What are the instructional practices being employed by elementary teachers in classrooms where the science achievement gap is less than predicted by school and district test data?
- To what degree do the instructional practices being employed by these elementary teachers reflect inquiry teaching practices and/or culturally relevant teaching practices with the potential to reduce the achievement gap in science?

- What do teachers feel are their most influential beliefs and experiences regarding teaching and learning science of elementary teachers in classrooms where the science achievement gap is less than predicted by school and district test data?
- What are the perceptions regarding learning science among the students of teachers who are successful at reducing the elementary science achievement gap?

The answers to the first two questions came largely from classroom observations as well as the Instructional Practices Log-Science (IPL-S) the three participating teacher completed over the course of the study. Data collected and analyzed from these sources illustrated that these teachers engaged in practices that reflect elements of both science inquiry teaching and CRP.

The physical characteristics of three teachers' classrooms illustrate that they intentionally arrange their rooms to create a science rich learning environment that efficiently facilitates their respective teaching styles with regard to students working collaboratively in variable groups and engaging in small group and whole class discussion. The way the teachers each set up their room with students sitting in clusters of two to six depending both on the teacher and the needs of the lessons, allow the teachers to facilitate the small group collaborative work observed during this study in which the students engaged in social interactions and collective sense-making as an integral and intentional part of the learning experience. Such an approach, where social interaction is an expected part of the learning experience, reflects elements of a constructivist approach to learning science in that it enables the construction of new knowledge and understanding through social interaction during the learning process and is indicative of

the characteristics of a science inquiry learning environment as well as a CRP (Bryant & Bates, 2015; Chiatula, 2015; Ladson-Billings, 1995; Tippett, 2009; Vygotsky, 1978).

In these classrooms, the teachers have also created an environment in which science is overtly displayed as a regular part of the learning. The presence of science learning goals as part of each class's daily agenda, the inclusion of non-fiction science books in the class library, the display of science-related artifacts, both publisher and teacher-created, and the presence of life science specimens in the classroom all indicate that these teachers not only place value on learning science, but also make efforts to show how science a part of the daily routine in the education of their students. This is in contrast to how science is often marginalized in lieu of prioritizing ELA and math, as is typical in many elementary schools (Johnson & Fargo, 2014; Sherman & MacDonald, 2008; Slavin, Lake, Hanley, and Thurston, 2014; Thomson and Kaufmann, 2013).

Another way in which the teachers created a science rich learning environment was through how much time and attention was given to science instruction on a regular basis. It is typical of many elementary teachers to marginalize science instruction in terms of resources and duration of science instruction, often as a result of a lack of comfort with teaching science as well as the prioritization of other topics such as ELA and math over science (Deniz & Akerson, 2013; Mensah, 2010; Sandholtz & Ringstaff, 2013; Smith, 2014). As reported on the IPL-S, however, Ashley, Miranda, and Tali regularly employed a variety of resources when teaching science, articulated various science learning goals, and engaged students in learning science for durations exceeding the average length of time many elementary teachers devote to science instruction. For example, Ashley, Miranda, and Tali reported high sense-making goals 34%, 41%, and 19% of the time

respectively. In addition to these, goals such as “Connect science concepts to everyday life,” “Cooperate with others,” “Develop children’s interests in science,” and “Develop reading comprehension skills” accounted for many of the reported goals. When it came to the use of science resources, textbooks were employed only 25.6% of the time for Ashley, 11.1% of the time for Miranda, and 29.3% of the time for Tali. The significance of these data is to illustrate how these three teachers are atypical of elementary teachers who are typically more likely to teach science at a rudimentary level through passive instruction and with a reliance on textbooks as the primary instructional resource (Diaconu, Radigan, Suskavcevic, & Nichol, 2012).

During the timeframe for which Ashley, Miranda, and Tali reported their science instruction practices through the IPL-S, the mean weekly duration of science instruction was 2.78 hours, 3.28 hours, and 2.37 hours respectively. By comparison, the average number of science instructional hours per week in grades 1 through 4 in across the nation in 2007-2008 was 2.3. During that same time, the 13 states with the highest NAEP scores in science indicated that in 4th grade, the average science instructional time was more than 3 hours per week (Blank, 2013). This illustrates that the mean duration of science instruction for all three teachers was greater than that of average elementary teachers. Additionally, the average duration of science instruction for Ashley is only slightly below that of the highest performing 4th grade teachers as measured on the 2007-2008 NAEP results while Miranda’s is slightly greater. This suggests that these teachers prioritize science instruction in terms of both frequency and duration taught, something that is at odds with what is the norm in most elementary settings in which science instruction tends to be marginalized in terms of time spent teaching (Sherman and MacDonald, 2008;

Slavin, Lake, Hanley, and Thurston, 2014). Furthermore, on the days they did not teach science, Tali indicated that she did not teach other subject while Ashley taught another subject (math or social studies) only four times. This stands out when compared to science elementary instruction across the country, where science is often deemphasized in favor of other content areas, such as ELA or math (Johnson & Fargo, 2014; Sherman & MacDonald, 2008; Slavin, Lake, Hanley, and Thurston, 2014; Thomson and Kaufmann, 2013).

Interestingly, while the mean weekly duration of science instruction for Ashley and Miranda were closer to the 3+ hour mean duration for the top 13 performing schools on the 2007-2008 NAEP science test, Tali's mean duration was similar to the 2.3 hour mean duration of science instruction for most elementary teachers (Blank, 2013). This difference might be the result of Tali teaching two sets of students both math and science while a partner teacher taught ELA and social studies. Working with a team teacher in this way might have constrained the time that Tali was able to allocate to science instruction as she would need to ensure that a given class was dismissed to their other teacher on time. What is interesting about this is that during the 2016-2017, when Tali similarly taught science and math to two classes, 68% of her students who qualified for the NSLP who scored "Meets Expectations" or "Exceeds Expectations" on the state's science assessment, a result that was significantly higher than the state's percentage for SIP who also scored "Meets Expectations" or "Exceeds Expectations." When this is considered in the light of the frequency with which the all three teachers reported teaching science, it is possible that Tali's students benefited from a more consistent, regular occurrence of science instruction. Ashley indicated that she taught science 60.7%

of the days during which she reported on her instruction. And while Miranda taught science for 100% of the time, she only reported on her instruction for 25 days during a 45-day quarter. In contrast, Tali reported science instruction for 73.5% of the time or 25 out of 34 days. Furthermore, for the days she indicated that she did not teach science, those reasons were primarily due to a substitute being present. Had Tali been present during the six days a substitute taught her students, it is possible that the frequency of her science instruction would have risen to 91.2% over the course of 34 days. This would result in her students receiving the greatest frequency of daily science instruction among the three teachers.

In the observed lessons of the three teachers, students would often engage in science through the use of authentic science practices that mirrored many of the characteristics of the SEPs defined by the *Framework of Science Education* (NRC, 2012). Chief among these were analyze and interpret data, construct explanations, and obtain and communicate information. Additionally, the students were often tasked with supporting their reasoning with their evidence in a manner similar to aspects of engaging in argument from evidence. In one of Tali's lessons, the students also used models in the form of simulations while in Miranda's lessons, not only did her students use simulation models, they also developed their own models. The results of the IPL-S further indicated that the teachers identified science activities that included collecting and working with data, explaining their ideas and thinking, supporting their thinking with evidence, communicating their ideas through models, drawings, illustrations, and discussions.

The use of genuine science practices is aligned with how the *Framework for K-12 Science Education* describes science learning as a process where students develop an

understand of core disciplinary knowledge and concepts through the application of science and engineering practices (NRC, 2012). When used in these different ways, SEPs are the means by which students engage in their learning as scientist in order to construct an understanding of the associated science concepts as well as communicate that understanding in the appropriate manner. Providing learning experiences in which students engage in different authentic SEPs with the purpose of obtaining information, collecting data, making comparisons, supporting claims through reasoning, developing and using models, constructing explanations, and communicating understanding is emblematic of a science-inquiry approach to teaching, especially given that the purpose of these learning experiences are for students to make their own connections and generate their own explanations and understandings of the science concepts (Kim & King, 2012; Passmore, Stewart, & Cartier, 2009; Wu & Hsieh, 2006). Additionally, when students learn through the application of these various SEPs in a social context where students work collaboratively in a sense-making process, they are engaging authentic practices in situated experiential learning that leads to the construction of new knowledge in a manner that is congruent to a social constructivist approach to learning science (Braaten & Windschitl, 2011; Watters & Diezmann, 2007; Windschitl, 2002). Furthermore, studies have shown that when the learning activities in the classroom are congruent to the learning goals of the state's science standards, as is the case with the lessons of these three teachers, student achievement improves, especially among traditionally low-achieving student (Marx, et, al, 2004; Rivet & Krajcik, 2004).

Understanding scientific concepts, as opposed to merely memorizing and knowing science facts, is frequently described as one of the main goals of the vision for

science education as described by the *Framework for K-12 Science* (NRC, 2012). It is important, then, to define that understanding, in the context of learning science through the application of authentic SEPs define in the *Framework*, is a sense-making process whereby students engage in ascribing meaning to their experiences with different scientific phenomena (Adams, et. al., 2017; NRC, 2012). In this way, understanding is more than just knowledge of some fact or concept; rather it is moving students towards being able to explain how something works by or why something happens in the natural world by reasoning through their experiences with different scientific phenomena in a way that makes sense to them. This can often occur through communication whereby students process and make sense of the phenomenon they engaged with as they attempt to articulate their experiences, through both verbal and written means, including illustrations and models (Adams, et. al., 2017).

Merely engaging in the use of authentic SEPs is not sufficient to consider a learning experience inquiry in nature. For a science learning experience to be inquiry-based, students need to engage in the scientific phenomenon through these practices with the purpose of attempting to make sense of it and develop an understanding of the science concepts that explain the phenomenon (Kim & King, 2012; NRC, 2012; Passmore, Stewart, & Cartier, 2009; Wu & Hsieh, 2006). The way that the teachers' lessons were sequenced, so that students would use their experiences, unpacked through the application of these SEPs, to attempt to describe and explain different scientific phenomena, supports an inquiry-driven approach to learning science. In each case, the phenomenon is experienced and understanding is sought through the application of the SEPs before a teacher-provided explanation is given (Kim & King, 2012; Passmore,

NRC, 2012; Stewart, & Cartier, 2009; Wu & Hsieh, 2006). Even when students were provided with learning goals and information texts prior to the experiential part of the lessons, the focus was on eliciting students' initial ideas through teacher questions or using questions to probe students' evolving understanding and engage them in sense-making that would include knowledge construction through the merging of experience with basic information about the phenomenon. Importantly, the teachers did not provide direction, explanatory instruction about the science concepts until after the students had experienced the phenomenon, engaged in observations or modeling, and began the process of developing understanding through group and teacher-led sense-making discussions.

This focus on student development of understanding through experience with different phenomena as opposed to rote memorization and recitation of science facts is aligned with recent science reform efforts (Berland & Reiser, 2008; Hokayem & Schwarz, 2014; Songer & Gotwals, 2012; Wu & Hsieh, 2006). The way in which these teachers used questions not only gave them the opportunity to elicit students' ideas about a topic, but also it allowed them to probe their understanding of the concepts they are studying. Additionally, their questions led to discussions that engaged students in the process of unpacking the learning experiences as part of their sense-making process, through the use of SEPs, that allowed them to articulate their evolving understanding of phenomena in their own words (Chin, 2007; Cochran, Reinsvold, & Hess, 2017). Furthermore, by making collaborative work an important element of their lessons, the teachers were taking advantage of the social nature of science learning whereby new ideas are developed as a result of the interactions that occur between students (Braaten &

Windschitl, 2011; NRC, 2012; Watters & Diezmann, 2007; Windschitl, 2002). To do this, all three make discussion and explanation a routine element of their science teaching. Through their use of questions to elicit student ideas, probe students understanding, and foster sense-making discussions, the practices of all three teachers reflect a social constructivist approach to science inquiry learning by putting the emphasis on student sense-making through experience, interaction and the use of authentic science practices (Braaten & Windschitl, 2011; Cavagnetto, Hand, & Norton-Meier, 2010; Watters & Diezmann, 2007; Windschitl, 2002). This focus on sense-making occurring through collaborative discussion also reflects the social interaction characteristic of constructivist learning (Bryant & Bates, 2015; Chiatula, 2015; Tippett, 2009; Vygotsky, 1978). The manner with which the teachers used their questions to both elicit student ideas and probe student understanding, at least in the early stages of exploring different phenomena illustrates how these teachers approach learning as a knowledge-building and sense-making experience, one in which knowledge construction is a continuously evolving process (Braaten & Windschitl, 2011; Cavagnetto, Hand, & Norton-Meier, 2010; Watters & Diezmann, 2007; Windschitl, 2002).

Ashley, Miranda, and Tali all exhibited a style of teaching in which the primary role of the teacher is that of a facilitator or guide through the learning experience as opposed to the didactic role of direction instruction and knowledge authority. When a teacher assumes the facilitator role, she is avoiding the likelihood of being perceived by her students as the source of knowledge at a point when the teacher expects her students to explore and discover some initial knowledge of the subject or phenomenon through experiential learning. Instead, by using questions to both initially elicit and later probe

students' ideas, all three teachers actively demonstrated that the responsibility for the constructing knowledge and understanding was on the students' shoulders (Brophy, 2010; Bryant & Bates, 2015; Doolittle, 2014; Tippett, 2009). In so doing, they did not assume the traditional role of being the knowledge authority in the classroom. Rather, they emphasized to their students that regardless of what their initial ideas about a topic might be, they would collectively work to develop an understanding through their explorations and investigations. In this way, the teachers assumed the role of facilitator and guide to learning (Brophy, 2010). Assuming such a role reflects how, in rigorous science inquiry, the students are the ones engaging in the process of actively constructing knowledge through authentic practices as opposed to passively acquiring it through didactic teaching methods (Brophy, 2010; Kim & King, 2012; Passmore, Stewart, & Cartier, 2009; Wu & Hsieh, 2006).

Ashley, Miranda, and Tali also placed a great deal of emphasis on the importance of science-specific terms, not only the vocabulary related to the science content their students were learning but also the use of terms related to the authentic science practices the students were engaging as the means by which they were learning. Both the use of science-specific language and the use of authentic SEPs affects the development of a science-rich classroom culture by inviting the students to assume the role of scientists in the classroom, in effect welcoming them into the culture of science learning as active participants as opposed to passive observers (Townsend, Brock, & Morrison, 2018).

In comparing the nature of the science inquiry characteristics exhibited in the observations of these three teachers with the data from the IPL-S on their self-reported goals, resources, and practices, there are several things that stand out. The most frequent

learning goals for each teacher reflect both elements of the observed lessons and the attitudes of the teachers regarding science and class community. In the observations of both Ashley's and Tali's respective classes, their students worked in groups to collect and analyze data, reason through evidence and scenarios, and explore phenomena. Given the collaborative nature of this work, it is understandable that both would cite "Cooperate with others" most frequently. Similarly, in describing their attitudes towards teaching science, both Ashley and Tali noted the importance of helping her students connect with the science they are teaching and expose them to things they have not experienced before. This makes it meaningful that both also cited "Develop children's interest in science" among their most frequent learning goals. Among Miranda's cited learning goals, she indicated "Connect science concepts to everyday life" most frequently. This matches up with the manner in which she would often use personal examples in class to help her students relate to the science they were learning, including when she talked about her dog's behavior, described a scar on her arm as an example of an acquired characteristic, and used pictures of her and her sisters to help her students recognize similarities and differences among organisms during their life cycle.

In comparing the data from the observations with the IPL-S data about the science-related student activities, two interesting distinctions becomes evident. While the frequency of both low and high sense-making activities for Ashley and Miranda are similar, when the high sense-making goals are added to these data, the occurrence of high sense-making rises from 17 to 38 for Ashley and from 30 to 52 for Miranda. This is understandable in light of the importance both Ashley and Miranda place on students' understanding and figuring out the scientific phenomena they are engaging with.

Conversely, when the cited high sense-making learning goals are factored in with the frequency of high sense-making activities reported by Tali, the occurrence rises from 8 to 21 and is still lower than the occurrence of low sense-making activities. This is not congruent with what was observed in two of her classes where students engaged in the adaptation simulations and the light interactions where reasoning and figuring things out was what the students were primarily engaged in. This could be the result of Tali underreporting or not recognizing her activities as high sense-making when she reported her daily instruction. Alternately, this could also be an indicator of the types of activities that followed these initial explorations of different phenomena. As Tali also indicated that her students used science textbooks more frequently than any other resource, it is possible that following these initial experiences, her instruction was more didactic in nature, focused on further making sense of the phenomena they had explored through the science text.

When examining the occurrence of different science practices, it is noteworthy that Ashley and Miranda seldom engaged their students in integrated science practices while Tali did not report any use of integrated practices. Given that the integrated practices on the IPL-S included “Develop and plan to test a hypothesis,” “Generate hypotheses based on scientific facts,” and “Manipulate a variable in an experiment,” this is not surprising when compared with the observed SEPs that the students engaged in for all three teachers. Throughout all nine observed lessons, the SEP “Planning and carrying out investigations” was never observed. While students were observed engaging in the collection and analysis of data as well as reasoning and constructing explanations, these practices were done with the purpose of describing and making sense of different

phenomena, though not through student planned investigations that required manipulating variables to test a hypothesis. Among the more frequently cited science activities for the three teachers were “Conduct a hands-on activity or manipulate materials,” “Make observations,” “Record data,” and “Examine scientific objects or specimens.” These activities are congruent with the tasks the students were observed engaging in.

Ashley, Miranda, and Tali frequently displayed practices and characteristics congruent to a CRP-informed approach to teaching. The way the teachers use questions to both elicit students’ ideas as well as probe for evidence of their reasoning and understanding (Chin, 2007; Cochran, Reinsvold, & Hess, 2017) also gives agency to students by visibly illustrating to them that their voices are important in the learning process (Brown & Crippen, 2016; Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995). In effect, they are inviting them into the culture of the science learning environment by showing that their ideas have a place there. This has the impact of reducing the tension that might otherwise exist if the students considered themselves as outsiders to the science classroom culture (Grimberg & Gummer, 2013; Ladson-Billings, 1995). Explicitly showing value for the voice, thoughts, and ideas of their students illustrates how Ashley, Miranda, and Tali create a culturally relevant learning environment, one in which their students feel that they are part of the culture of learning, as opposed to science learning being viewed as a different culture from their own (Grimberg & Gummer, 2013; Ladson-Billings, 1995). By recognizing the value of their students’ voices, in particular by how they ask for their thoughts at the very beginning of a lesson, they help break down the barriers between the science content and the students who are coming to it from their own personal and cultural frame of

reference, with their own ideas and possible misconceptions (Ladson-Billings, 1995; Phelan, Davidson, & Cao, 1991).

One of the ways teachers created a positive, risk-free learning environment where student feel empowered as opposed to frightened of the unknown was through the use of positive class rituals and procedures that bring a sense of stability and familiarity to the classroom (Mullis & Fincher, 1996). In providing a safe place for the inherent risk-taking in learning, Ashley, Miranda, and Tali are further breaking down the barrier between what might be perceived as the more formal, inflexible culture of science education and the way her students approach learning based on their own experiences and personal cultural identities. Positive rituals provide a set of agreed upon expectations that provide stability to the class environment. And by addressing such distractions and disruptions through non-punitive actions, the teachers shift the focus of addressing the behavior from themselves to their students. Through their actions, the use of positive rituals to focus student attention and non-punitive steps to address disruptive or distracting behavior, these teachers ensure that their students feel comfortable and safe in their learning environment. In so doing, the teachers enable their students to develop a positive view of science learning and to interact with that culture in a way that they might otherwise not be as comfortable or willing to do (Ladson-Billings, 1995; Phelan, Davidson, & Cao, 1991; Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995). When these actions create a sense of consistency and familiarity in the classroom, students are more likely to be engaged because they feel comfortable and safe in the learning environment (Mullis & Fincher, 1996).

Teachers who communicate high expectations and positive feedback articulate to their students that they are capable of being successful in class, something that is a defining characteristic of culturally relevant pedagogy (Johnson, 2011; Ladson-Billings, 1995; Laughter & Adams, 2012; Powell, Cantrell, Malo-Juvera, & Correll, 2016). The way these teachers communicate high expectations as well as affirm not only their belief in their students' abilities but also their hard work once they have achieved their accomplishments plays a significant part in creating a culture of science achievement that her students feel comfortable and confident learning in. In so doing, their students can see themselves as capable of accomplishing what she sets out for them to do. (Forsyth & McMillan, 1981; Ladson-Billings, 1995; Laughter & Adams, 2012). By overtly connecting their efforts to their successes, Ashley, Miranda, and Tali are reinforcing a positive association for her students with regard to how they are capable of learning science (Forsyth & McMillan, 1981).

Through the different, relatable examples and stories they use in their lessons, Ashley, Miranda, and Tali make science personally relevant and meaningful in a manner that helps their students not only see the importance in what they are doing but also how it connects to their own values and lives. These efforts help foster engagement because the students see why they are learning what they are learning as a reflection of their own identities and culture (Grimberg & Gummer, 2013; Ladson-Billings, 1995; Laughter & Adams, 2012; Lee, 2004). These teachers also foster engagement through the use of authentic science practices that engage students in social interaction as part of the sense-making process.

The way the teachers sequence the learning so that the students engage with a scientific phenomenon with the goal of unpacking that phenomenon through the application of SEPs in order to developing a conceptual understanding of the science behind the phenomenon also reflects elements of CRP where learning is focused on understanding and where the teacher's role is to pull information from their students, not push it in (Ladson-Billings, 1995; Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995). This recognition, that knowledge is something that is constructed through a social process and experience as opposed to something that is fixed, is not only one of the main elements of a culturally responsive pedagogy but also of constructivist science inquiry practices (Bryant & Bates, 2015; Chiatula, 2015; Ladson-Billings, 1995; NRC, 2012).

Similarly, the way Ashley, Miranda, and Tali assumed the role of facilitator of learning and worked to create a student-centered learning environment that focused on sense-making through collaborative social group work is evidence not only for how these teachers take an inquiry-focused approach to science but also of the way these teachers use elements of CRP to create a positive, supportive learning environment (Ladson-Billings, 1995; Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995). In assuming the role of facilitator, these three teachers are surrendering their authority as the source of knowledge in the learning environment and putting that power in the hands of the students through how they engage in act of constructing knowledge through their experiences, social interactions, and user of authentic SEPs. This, in turn, breaks down the metaphoric barrier that exists between the traditional classroom authority-driven culture and the cultural identities of the students by showing how the

students are responsible for creating the science learning culture in their class, one that reflects their own ideas and that they can see the value of being a part of (Grimberg & Gummer, 2013; Ladson-Billings, 1995).

Through the way their students constructed explanations of phenomena, acquired and analyzed data, used evidence to support claims and communicate their reasoning, and communicated their ideas through discussion, not only did their students engage in authentic science inquiry practices, they also engaged in practices that support a positive, student-centered classroom environment that reflects many of the characteristics of CRP (Brown, 2017). The same way that these SEPs create an authentic science inquiry learning environment also reflect attributes of a culturally relevant setting through the focus on collaborative sense-making and higher order reasoning (Wlodkowski & Ginsberg, 1995). As opposed to knowledge being viewed as rigid, this focus on learning through sense-making is a characteristic of culturally relevant pedagogy, one that fosters a sense of community, empowers student success, and changes the traditional knowledge dynamic in the classroom (Ladson-Billings, 1995; Laughter & Adams, 2012; Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995).

Furthermore, when students of these teachers engage in these authentic SEPs as part of the process of constructing knowledge, they are also engaging in the inherently social nature of how scientific knowledge is construct (Brown, 2017; NRC, 2012). That the science knowledge-building experience is a social interaction is not only congruent with a social constructivist approach to learning science, but also reinforces the notion that both teacher and learners are part of a shared community (Bryant & Bates, 2015; Chiatula, 2015; Ladson-Billings, 1995; Vygotsky, 1978).

The answer to the third question came primarily from the interviews conducted with each teacher following the completion of the nine classroom observations. In the analysis of their responses, it became evident that these teachers share a common set of beliefs and exhibit a similar attitude about teaching science and their students. Also, these teachers share a similar set of experiences that inform these beliefs and attitudes. In many ways, Ashley's, Miranda's, and Tali's experiences are typical of elementary teachers in general. Their prior experiences did not provide them with a background in science that allowed them to be initially comfortable with teaching science. Similarly, they did not initially have a range of hands-on science experiences to draw upon when planning their lessons. This lack of experience with both science content and science inquiry practices is common of elementary teachers (Akerson, et. al., 2009; Mensah, 2010; Sherman & MacDonald, 2008; Slavin, Lake, Hanley, and Thurston, 2014). Like many elementary teachers, these teachers initially had negative feelings about teaching science (Sandholtz & Ringstaff, 2013). Additionally, elementary teachers who do teach science often end up teaching in a manner Tali experienced during her student teaching experience; that is through didactic, teacher-centered instruction that focused on test performance over teaching through inquiry and exploration (Diaconu, Radigan, Suskavcevic, & Nichol, 2012; Johnson & Fargo, 2014).

More significantly, however, are the ways in which these teachers are atypical of elementary teachers. All three described enjoying teaching science and actively sought out professional learning to help them be more prepared at offering hands-on learning experiences for their students. Ashley identifies herself as a "person who loves to learn" and who "likes interesting things" and "trying to figure out things." This results in her

persistence in self-improvement and in providing the best learning experience she can for her students. Similarly, Miranda has come to enjoy teaching science, largely because of her students' own enthusiasm for the subject, something she credits to the way she teaches science, something that is also atypical of many elementary teachers. Tali's evolution with regard to coming to enjoy teaching science is largely influenced by her positive PD experiences.

All three teachers also describe the ways in which professional learning, either through mentor partnering or provided by the district's science content specialist, positively impacted the way they feel about and teach science. This, too, is atypical of the experiences of many elementary science teachers. Elementary teachers typically describe receiving little PD related to science as priority is given to ELA and math in terms of the time, substitutes, funding, and resources expended on providing meaningful professional learning (Adamson, Santau and Lee, 2012; Johnson & Fargo, 2014; Thomson & Kaufmann, 2013). Tali's description of how she taught science prior to the current year is more in line with what most elementary teachers report. Because of the lack of support, science background knowledge, and limited experience with science inquiry methods, many elementary teachers teach science through a knowledge-centric approach that focused on memorizing science content knowledge often to the exclusion of authentic science practices (Thomson & Kaufmann, 2013).

Ashley, Miranda, and Tali describe the importance of using questions in the context of inquiry in a manner that allows their students to develop their understanding through discussion and sense-making as they attempt to put their thoughts about the phenomena they are studying into their own words (Chin, 2007; Cochran, Reinsvold, &

Hess, 2017). Furthermore, the way the teachers use of questions and discussion to not only assess understanding but also to create a context in which ideas are developed, evidence analyzed, and explanations are reasoned reflects the social constructivist ideas that learning takes place through a knowledge-constructing process whereby new understandings are considered through the lenses of experience and prior knowledge and reconciled through social interaction (Bryant & Bates, 2015; Chiatula, 2015; Tippett, 2009; Vygotsky, 1978). Finally, the use of questions as a means of fostering discussion and sensing-making through dialogue reflect the way questions can be used in a science inquiry setting to encourage students to elaborate on their understanding as opposed to evaluating the accuracy of their understanding of the knowledge (Smart & Marshall, 2013). The focus on vocabulary exhibited by all three teachers is also one of the ways that they create a science-rich learning environment where their students can feel comfortable assuming the role of scientists (Townsend, Brock, & Morrison, 2018).

All three teachers described how experiential learning and directly engaging with some scientific phenomenon with the purpose of constructing an understanding of the nature of the science behind that phenomenon is the way they feel their students can best learn science. Additionally, it is a chief characteristic of an inquiry-driven approach to science shared by all three teachers. (Kim & King, 2012; Passmore, Stewart, & Cartier, 2009; Wu & Hsieh, 2006). Their approach and underlying beliefs regarding how student's best learn science are also in line with a social constructivist approach to teaching science through inquiry and the use of authentic science practices. All three teachers focus on engaging the students through an exploration of a natural phenomenon, often through hands-on experiences, followed by collaborative sense-making discussions

aligns with a reform-based approach to science teaching that places the emphasis on understanding through authentic practices and constructing explanations that are supported by evidence and reasoning (Braaten & Windschitl, 2011; NRC, 2012; Watters & Diezmann, 2007; Windschitl, 2002). Furthermore, all three teachers feel that they should use real world examples to help their students connect with the science concepts they are learning. Through the use of real world examples and authentic practices these teachers demonstrate a constructivist approach to science that leverages sustained engagement through personal relevancy (Brooks & Brooks, 1999; Faircloth & Miller, 2011; Oldfather, 1993) This makes them atypical of many elementary teachers, whose lack of experience results in a didactic approach to teaching science (Diaconu, Radigan, Suskavcevic, & Nichol, 2012).

The teachers in this study believe the role of the teacher is to be a facilitator of learning. By assuming the role of facilitator instead of the more traditional role of knowledge authority, these teachers exhibit not only an inquiry-driven approach that focuses on students as problem solvers, but also reflect elements of a social constructivism approach to authority in the classroom (Brophy, 2010; Bryant & Bates, 2015; Doolittle, 2014; Tippett, 2009). This role as facilitator and as well as how all three teachers use questions to not only acquire evidence of understanding, but as part of the process by which their students have to figure out that understanding, also mirrors characteristics of constructivism whereby knowledge is constructed as the learner incorporates new experiences with prior knowledge in a social context (Braaten & Windschitl, 2011; NRC, 2012; Watters & Diezmann, 2007; Windschitl, 2002).

Ashley, Miranda, and Tali all describe having high expectations of their students and a belief that their students are capable of achieving their expectations. Having not only high expectations for their learners, but also a deeply held belief in the ability to meet or even exceed expectations helps to foster a positive attitude towards science and an atmosphere of achievement in class. This creates a class culture where students are able to achieve success in part because they know their teachers believe in them (Ladson-Billings, 1995; Laughter & Adams, 2012; Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995). Additionally, when teachers have high expectations of students in the context of science, they are more likely to engage them through science inquiry because they believe that their students will be able to learn science successfully even as the teacher assumes the less hands-on role of facilitator (Lotter, Harwood, & Bonner, 2007). All three teachers also provide a safe space through their use of open classroom discussions in a way that helps to foster a positive learning environment where students can feel confident in their abilities and display a willingness to share their ideas, even if they might represent misconceptions (Ladson-Billings, 1995; Phelan, Davidson, & Cao, 1991).

All three teachers recognize that the community served by their respective schools has an impact on the way their students engaged in the learning experience with them, especially in the context of science where often times the degree of background knowledge and experience can vary widely based on one's experiences at home (Dearing et. al., 2016; Ladd, 2012; Sirin, 2005). Teachers whose practices are informed by CRP will recognize the influence and importance that family plays in supporting learning and can leverage that support in a way that bridges the metaphorical divide between the

classroom and the family/community (Brown & Crippen, 2016; Grimberg & Gummer, 2013; Ladson-Billings, 1995; Powell, Cantrell, Malo-Juvera, & Correll, 2016). This connection to community and recognition of the characteristics of their learners is important, as it illustrates how these teachers takes into account the cultural identities of their students and their families as well as how she sees her role as one in which she is giving back to the community by empowering its youngest members (Gao & Wang, 2016; Grimberg & Gummer, 2013; Ladson-Billings, 1995). Recognizing both the cultural distinctions and biases as well as the different perspectives and life experiences between oneself and one's students is an important element of culturally relevant approach to teaching, given that in order to break down the traditional student-teacher dynamic in the classroom and learning experiences that are relevant and meaningful for the students, a teacher must recognize that the experiences and values of their students is different from their own (Gao & Wang, 2016; Grimberg & Gummer, 2013; Ladson-Billings, 1995; Phelan, Davidson, & Cao, 1991).

This makes is noteworthy that in Miranda's case, she did not describe a positive, supportive connection between her and her students' parents. The degree of which this lack of connection might have impacted the performance and attitudes of the students in the class is speculative; however, it is also worth noting that several of Miranda's students expressed that they did not feel as if they were a part of the science learning community Miranda tried to create. Despite the efforts Miranda described taking at the start of the school year at creating a positive learning community, some of her students did not share those feelings. It is possible, and worth further investigation, that the negative feelings towards the parents of her students might, in manner, have had an

impact on these perceptions, even if on an unconscious level. The lack of positive community feelings does not, however, seem to negatively impact the feelings her students have for her as an individual given that all of her representative students had very positive things to say about her.

The teachers in the study described slightly different ways in which they engage with students from low SES backgrounds. Ashley spoke of the importance of language and the use of science-specific vocabulary as crucial to her students being able to see themselves as scientists. As described earlier, a focus on science-specific vocabulary also serves a function of inviting students to become active participants in the culture of science learning (Townsend, Brock, & Morrison, 2018). Miranda described how she tries to make sure all of her students' voices are heard throughout the learning experience. The way in which Miranda shows how she values student voice and the expression of their own ideas as part of the sense-making learning experience is another characteristic of a CRP and has the impact of encouraging students to see themselves as part of the culture in the classroom (Brown & Crippen, 2016; Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995). Additionally, Miranda also talked about how she uses hands-on science experiences to allow students to relate to the broader, more abstract science concepts they are learning about. By providing a safe place for students to feel comfortable with the risk taking that is essential in an active learning environment, Miranda is taking steps to ensure that the culture of science learning in her classroom is not something foreign to her students but rather is something they can consider themselves a part of (Brown, 2017). Tali described how she tries to make science meaningful for her students by connecting it to things they are interested in as well as

through encouraging them to express their own ideas about what they are learning. Tali's efforts to make learning personally relevant and meaningful for her students, particularly through discussion and collaborative group work, not only aligns with a constructivist informed science inquiry approach to teaching but also with elements of CRP that define meaningful learning and something that is relevant to the students based on their personal identities, values, and beliefs learner (Grimberg & Gummer, 2013; Ladson-Billings, 1995; Lee, 2004; Oldfather, 1993).

Additionally, these teachers described different ways they differentiated the learning for their students, from Ashley's use of scaffolded questions and texts to Miranda's use of her science playlist to how Tali differentiates through scaffolded note taking and reading levels. Recognizing the differences among their students, as well as taking action to differentiate the learning based on their needs illustrates a culturally relevant approach to teaching (Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995). Differentiating their teaching by providing self-paced opportunities to work in a manner that appeals to their students, by scaffolding resources and access to informational texts, and by engaging students through personalized questions are all ways another way in which they bridge the traditional divide between subject/teacher and student (Grimberg & Gummer, 2013; Laughter & Adams, 2012; Lee, 2004; NRC, 2012).

The final research question is primarily addressed through the results of the three different student focus groups. In general, the representative students from all three classes shared many of the same perceptions regarding their experiences with learning science and their feelings about their teachers. In general, the students from all three

classes expressed very positive attitudes about learning science as well as about their respective teachers. Similarly, the students all recognized the ways that their teachers helped them to understand what they were learning, including by making science interesting, by making relevant connections, and by engaging them in a variety of experiences, including hands-on learning. Their students recognize that understanding, not just knowledge and facts, is the goal of science learning (NRC, 2012). Their students find themselves in the roles of genuine scientists, not only through their use of hands-on practices, but also by learning science in a social context when working collaboratively (Bryant & Bates, 2015; Chiatula, 2015; Tippett, 2009; Vygotsky, 1978). They also recognize how their respective teachers' different instructional practices, including the use of hands-on engagements, diagrams, specimens, and relevant connections are all ways that help them to better understand what they are learning (Brooks & Brooks, 1999; Faircloth & Miller, 2011; Oldfather, 1993). It is also worth noting that the positive attitudes towards science communicated by these student groups was also mirrored in the students' attitudes and engagement as witnessed in the observations of all three classes. These positive perceptions are to be expected from the science learning environments fostered by their respective teachers, especially with a focus on social interaction and discussion, authentic science inquiry practices, meaningful connections (Braaten & Windschitl, 2011; Cavagnetto, Hand, & Norton-Meier, 2010; Watters & Diezmann, 2007; Windschitl, 2002).

The impact of the way Ashley, Miranda, and Tali each employ a culturally relevant style of teaching is also evident in the way their students express their confidence as science learners, as well as in their feelings of how their teacher genuinely

cares not only about their success in class, but also about them as individuals (Ladson-Billings, 1995; Laughter & Adams, 2012). Also, all three representative student groups described a variety of ways that their teachers helped support them as learners and empowered them to be successful. Interestingly while Ashley's and Tali's students unanimously agreed that they felt that they were part of a positive, supportive, science learning community, the feelings of Miranda's students varied. Some of them did feel that they were part of similarly supportive learning community while others expressed feelings of disconnect depending on the circumstances and interactions in the classroom. Despite the different feelings regarding the whole class learning community, the impact of the positive learning environments the three teachers provide is evident not only in the positive regard these students have for science and their teacher, but most significantly, in how they believe their teachers have faith in them as science learners (Brown & Crippen, 2016; Ladson-Billings, 1995; Powell, Cantrell, Malo-Juvera, & Correll, 2016; Wlodkowski & Ginsberg, 1995). It is also important to note that the positive feelings their students have towards them contribute not only to the willingness of the students to engage in the science learning experiences provided by their teachers, but that these feeling, greatly influenced by the positive relationships fostered by the collective efforts of their teachers, also contributes to the ability of these students to achieve the high standards of performance their teachers expect of them (Kipkoech, Kindiki, & Tarus, 2011; Roorda, Jak, Zee, Oort, & Koomen, 2017).

A spectrum of different characteristics, both reflective of science inquiry practices and CRP were evident in the classrooms, attitudes, and perceptions of both the teachers and their students. It is likely the it was combination of these factors that was ultimately

responsible for the positive science learning experiences observed in the lessons and positive attitudes and perceptions shared by the students and teachers. What makes this important is that it is likely that had these teachers exhibited a narrower range of attributes or characteristics that primarily reflected either science inquiry or CRP instead of both, the results of this study would not have found such a positive science learning environment. A teacher who has command of both science content knowledge and is comfortable teaching science through inquiry practices will not be as successful in a highly diverse class if that teachers does not also take steps to create a more personally relevant, inclusive, and supportive learning environment. Similarly, a teacher who works to create a positive learning environment where every student understands the importance of what they are doing and sees themselves as successful learners will not be successful at teaching authentic, meaningful science if they are not able to engage the learners through science practices in an inquiry setting. Of these many practices exhibited by Ashley, Miranda, and Tali, it is likely that the most impactful were the positive attitudes and beliefs these teachers held that all of their students could be successful in learning science through these experiences. These teachers genuinely cared for the success of their students as learners and individual human beings, not merely as test scores that contributed to their school ratings.

SIGNIFICANCE OF SCIENCE PRACTICES AND CRP

The persistence of the achievement gap in science is well documented, with studies indicated that the disparity in science achievement between marginalized populations and privileged populations manifesting as early as Kindergarten (Curran & Kellogg, 2016). As measured on the 2015 National Assessment of Education Progress

(NAPE) science assessment, 4th grade students who were not eligible for participation in the National School Lunch Program outperformed their counterparts who were eligible by a mean score of 169 to 140 (NCES, 2015). The reasons for this performance gap are varied and complex, from factors related to poverty that occur both inside and beyond the school walls, including access to health care, limited life experiences, school resource allocation, and recruitment and retention of quality teachers (Balfanz & Byrnes, 2006; Dearing et. al., 2016; Duke, 2000; Garcy, 2009), as well as how those factors aggravate systemic challenges to effective inquiry-based science instruction in the elementary school setting, most notably the limited science knowledge and inquiry experiences of teachers coupled with the marginalization of science instruction in terms of time, PD, and resource support (Akerson, et. al., 2009; Mensah, 2010; Sandholtz & Ringstaff, 2013).

In light of this persistent problem, there is a need to identify the characteristics of effective teachers whose low SES students are able to outperform their low SES peers vis-à-vis science achievement. Previous studies have illustrated that teachers who engage certain sets of practices can have a positive impact the science achievement of students from different marginalized backgrounds. One study found that professional development that increased the use of hands-on activities, focused on lesson planning, developed student science vocabulary, and supported science inquiry practices, such as students initially exploring concepts through investigations instead of the teacher directly explaining science content to them, enhanced teacher capacity to effectively teach science in a high poverty school. This, in turn, accounted for significant improvements on state standardized tests, particularly among economically disadvantaged students (Jackson & Ash, 2012). In this study, elementary school teachers who taught ethnically diverse and

economically disadvantaged students engaged in PD that included purposeful planning around standards-focused activities, 5-E science inquiry instruction, and the development of academic content vocabulary. It is noteworthy that some of the practices that were the deliberate focus of the PD in the Jackson and Ash (2012) study, namely student-focused activities, hands-on science inquiry teaching, the purposeful planning around standards-based learning goals, and a focus on academic science vocabulary, were also exhibited by Ashley, Miranda, and Tali, although these three teachers never received specific PD on the use of these practices to leverage academic success among low SES students.

Another study found that the students of middle school science teachers identified as “effective” (based on the Horizon Research Local Systemic Change Classroom Observation Protocol) showed increased science achievement when compared with ineffective teachers, in particular among non-White students. The teachers in this study had received three years of PD through the Model School Program, specifically on effective, standards-based science instruction. In further case studies of these teachers, two teachers identified as effective believed that their students could learn more and develop a deeper understanding of concepts through hands-on investigations and learning through problem solving (Johnson, 2009). These two effective teachers also felt that science was not about memorizing but about learning the processes of science. These teachers also came to enjoy teaching science and felt that this love for science impacted how their students came to see science in a positive way. The characteristics of these two teachers are similar to many of the characteristics of Ashley, Miranda, and Tali, in particular how they all share a love for teaching science, belief that science is as much about developing understandings as it is about engaging in practices, and the feeling that

their students could be capable of success in leaning science. It is also noteworthy that the goals of the PD the teachers in the Johnson (2009) study included a focus on standards-based science instruction, a trait also exhibited among the three teachers in the current study.

Geier, et. al. (2008) found that best practices in curriculum, including inquiry-based science units, combined with professional development and technology training can produce positive gains on standardized tests among historically underserved urban populations. In this study, 7th and 8th grade teachers participated in a three-year PD effort that focused on a project-based inquiry model of curriculum unit development. These project-based units were designed around authentic, relevant, and familiar scenarios that were contextualized by overarching questions. Additionally, the project-based curriculum was aligned with the state's science standards. The findings suggest that the key to the success of this multi-year PD was that it was highly specified and highly developed for the large urban school district it was implemented within. The findings of the Geier, et. al. (2008) study, that is the use of a standards-based, project-based learning curriculum that both focused on relevant issues pertinent to the community in which the curriculum was being implemented and was well aligned to the learning goals of the science standards, illustrate elements of successful science PD, curriculum development, and instruction that are not evident in the practices of the participants in the current study, in particular how Ashley, Miranda, and Tali did not engage in project-based learning or community-related issues in science. The teachers in the current study did, however, engage in science inquiry practices that were well aligned with the state's performance indicator learning goals, something that was part of the middle school curriculum PD.

In addition to studies that look at science-specific practices, resources, and PD that showed impacts on reducing the science achievement disparity among different groups, there have also been studies that have also looked at the impact of CRP on science achievement. In their study of the impact of multi-year PD to support the creation of culturally relevant science units in K-8 schools that served a Native American community, Grimberg and Gummer (2013) found that when efforts were made to connect science concepts taught through hands-on practices with topics and elements that were culturally familiar and important, including presentations made by tribal elders, not only did student achievement increase, but also teachers reported increased confidence in their ability to teach science content as well as enact equitable teaching strategies. Participants in the study made explicit efforts to connect core science concepts, such as acceleration, with culturally familiar topics, such as arrow making and throwing. Additionally, participants also invited members of the community, specifically tribal elders, to make presentations on culturally relevant topics that connected to the science concepts in the unit. Interestingly, while Ashely, Miranda, and Tali did include examples in their instruction that were familiar and relatable to their students, this particular element of CRP, that is making explicit connections between the science concepts and culturally relevant topics that reflect important elements of the heritage and cultural identities of the community at large, was not evident in the practices of the three teachers in the current study. Further, while Tali described making explicit efforts to directly connect her science instruction with the families of her students, these efforts were not focused on culturally connections but rather on maintaining open communication and fostering a supportive partnership.

In a study of English Language Learner (ELL) populations in a culturally diverse elementary school, Lee (2004) described an example of instructional congruence whereby a science unit about weather included terms in Spanish and made references to locations and climate familiar to the Hispanic students. The six participating teachers helped to modify an existing set of standards-aligned curriculum materials to include these culturally relevant elements. The study found that the inclusion of these familiar terms and references in the native language of the students allowed them to make a stronger connection with the weather science concepts they were learning. While the Lee (2004) study illustrates the potential for making culturally recognizable references in the language familiar to the students, it was not evident that the teachers in the current study made any efforts, beyond asking the researcher for Spanish language versions of the parent and student consent forms, to expand their instruction to include language examples and connections with any ELL students that might have been present in their rooms. It is important to note that the curriculum materials in the Lee (2004) study did make reference to the inclusion of hands-on and inquiry lessons, the focus of the research was on the impact of the inclusion of the native language and culturally familiar elements and not the impact of science inquiry practices.

A study of middle school science teachers in a largely Hispanic community focused on teachers receiving PD focused specifically on infusing CRP practices into science instruction (Johnson, 2011). While the PD included elements of science inquiry teaching methods, the primary focus was on elements of CRP, including positive expectations, cooperative learning, and meeting the needs of culturally diverse learners. The analysis of the results of case studies of two participating teachers showed that these

teachers were able to transform their classrooms into more effective science learning environments for their Hispanic students and that these teachers showed an increased effectiveness in their practices and confidence with regard to teaching science to their Hispanic students. In comparing this results of the Johnson (2011) study to the outcomes of the current study, although Ashley, Miranda, and Tali created a positive, inclusive science learning environment that included elements of science inquiry and CRP, their efforts were not specifically tied to meeting the needs of a specific ethnicity.

In another example, a middle school science teacher who included topics of social justice related to science in her lesson found that her students outperformed expectations, despite the cautioning of his colleagues that such topics would only create an atmosphere in the class of racial tension and would result in numerous inappropriate, racial comments (Laughter & Adams, 2012). In this study, the teacher planned to include a science fiction text as a hook to engage her middle school students at the start of her astronomy unit. The text was one that addressed issues of social justice in the context of a science fiction story. The teacher, who was a coauthor in the study, planned to use the text to illustrate the connections between the bias presented in the story and the bias that existed in the discipline of science. The teacher found that her students were actively engaged in the learning and, by her measure, showed evidence of developing an understanding of the nature of bias in science. The teacher attributed her success, in part, to her own belief that her students were capable of more than her peers believed. While Ashley, Miranda, and Tali did not engage their students through similar, explicit connections related to bias that they might find relatable based on their own lived experiences, they did share the common characteristic with this teacher that they held high expectations for their students

and believed that they students were capable of being successful in learning science and meeting their expectations.

While these different cases examine efforts at reducing science achievement gap and the disparity in student performance between different demographic groups, they tend to consider the solution to this challenge as either one that can be solved through a focus on improving science instructional practices and science curriculum resources or one that can be solved through the application of different elements of CRP. And while in some cases, there was some overlap between findings in studies focused on science curriculum and practices with CRP, such as how the teachers in the Johnson (2009) study also exhibited high expectations and belief in the capabilities of their students, the overlapping characteristics of CRP were not the focus of that study. Similarly, while the participants in the Johnson (2011) study received training on both science inquiry practices and CRP with regard to the Hispanic students in their classes, the focus of the PD the teachers received and the outcomes of the study were primarily on the impact of the CRP and how it affected teacher practices and attitudes. Additionally, most of these studies examined possible ways to address disparities in science achievement that manifest between different ethnicities, including the impact of language, with few studies examining possible ways to address the science achievement gap specifically in the elementary setting and specifically with regard to poverty (Geier, et. al., 2008; Lee, 2005). What potentially limits these studies is that each of them focused on just one part of the whole spectrum of potential influences of student success.

The significance of the current study is that it is not focused exclusively on one particular approach, either science inquiry or CRP. Neither is it intentionally focused on

measuring the expected outcomes of efforts aimed at reducing the achievement gap in science either through PD on the development and implementation of a specifically designed curriculum or through the impact of PD on developing CRP capacity among teacher participants. Instead, this study examined the phenomenon of teachers in select classes of predominantly low SES students whose previous year's low SES students not only outperformed their district SIP peers but also manifested a smaller achievement gap when compared to their non-SIP peers across the entire school district with regard to science achievement. That this occurred without any form of professional development tailored specifically to the goal of reducing the science achievement gap makes this phenomenon all the more exceptional.

While the teachers in the current study reported receiving productive, science-specific PD and described the positive impacts of the PD efforts, their PD experiences in this regard were no different than the experiences of their fellow teachers within the same district and were not for the specific purpose of reducing the achievement gap in science. Additionally, these teachers did not report receiving any specific PD focused on implementing CRP with their students. Yet, despite the lack of targeted professional learning on ways to reduce the science achievement gap, the low SES students of these teachers demonstrated during the year prior to this study a capacity to both outperform their district level low SES peers and to show a reduced achievement gap when compared to their non-SIP peers across the district on the state's end of the year science assessment.

The significance of this study is that it examined the challenges of reducing the achievement gap in elementary science for low SES students at the intersection of both science inquiry practices and CRP. While other studies may have considered solutions to

this challenge through either the impact of science inquiry teaching practices or through the application of CRP, this study demonstrated how these three teachers exemplified characteristics of both of these approaches. By examining this as a phenomenon manifested as a result of the practices, attitudes, and beliefs of the three teachers, instead of focusing on this phenomenon as overcoming either a science teaching problem or a classroom-student cultural disconnect, this study identified a set of characteristics that illustrated how these teachers both employed an inquiry and social constructivist approach to teaching science as well as engaged in a culturally responsive teaching style emblematic of CRP practices. Furthermore, by focusing on this as a phenomenon that was occurring in these classes as opposed to an anticipated outcome of a specific set of strategies or resources that were part of a program of PD or curriculum development, this study was not limited in its scope with regard to what practices it expected or examined. Importantly, with few exceptions, all three teachers manifested very similar practices, attitudes, and beliefs about effective science teaching including the need for students to engage in authentic science practices, the effectiveness of student discussion and voice in sense-making, the belief in the capacity for their students to be successful in learning science, and the importance of students engaging in hands-on learning around scientific phenomena as part of an inquiry-approach to science. Also, with the exception of a social justice component and certain specific SEPs, Ashley, Miranda, and Tali collectively exhibited most of the defining characteristics of both inquiry-focused science teaching and CRP, many of which were not described in the outcomes of the other studies. These included the valuing of student voice, the focus on developing understanding, the creation of a positive learning environment through positive rituals and non-punitive actions, the

use of questions to elicit student ideas and probe student understanding, and the identification of the teacher in the role of facilitator of learning. This study identified many additional characteristics evident in these teachers' practices that were not the focus of previous studies.

IMPLICATIONS AND FURTHER RESEARCH

The underlying purpose of this study was to examine the phenomena of teachers that have been successful at reducing this achievement gap for their students with regard to poverty and to identify and describe practices, attitudes, and beliefs held by these teachers that reflect elements of both an inquiry approach to teaching science and CRP that have been demonstrated as being effective at reducing the science achievement gap under various circumstances. As such, this study has been successful in qualifying the practices of three such teachers with regard to their congruence to both science inquiry teaching and CRP. Furthermore, this study found that these teachers, despite lacking PD experiences specific to reducing the achievement gap in science, exhibited many of the same characteristics with few exceptions. While the limitations of this study do not allow for causation to be supported, in that there was no attempt to determine a specific cause and effect relationship between specific actions and resulting outcomes of science achievement, the outcomes of this study do offer several implications and avenues of further study.

Studies have shown that when teachers implement authentic science practices in the context of inquiry-based instruction, the achievement gap in science is reduced (Geier, et. al., 2008; Jackson & Ash, 2012; Johnson, 2009). By teaching science through authentic science practices in a science-rich, inquiry setting, students build their

knowledge of science concepts based on shared experiences that allow for students to process phenomenon through social interaction and discussion as a sense-making experience, one that does not rely heavily on taking advantage of prior knowledge and uneven personal experiences to allow for success. Similarly, studies have also illustrated that when teachers engage in culturally relevant teaching practices, their students are able to achieve success in science (Grimberg & Gummer, 2013; Laughter & Adams, 2012; Lee, 2004). By creating a positive science learning environment where students are empowered to be successful and where they can see themselves as supported members of the science learning community with shared values and priorities, as opposed to outsiders to a distinctly different culture and climate, students are able to achieve success because they see the significance of what they are learning, and they place value on the experience.

Implications.

When looking at ways to address the science achievement gap in elementary schools serving low SES communities, the outcomes of this study suggest that an approach that includes supporting science inquiry teaching practices and CRP is worth investigating. Brown (2017) makes the case for the complementary nature of several of the *K-12 Science Framework*-defined SEPs (NRC, 2012), specifically obtaining, evaluating, and communicating information, constructing explanations and designing solutions, and developing and using models. Brown also found that analyzing and interpreting data, using mathematics and computational thinking, and engaging in argument from evidence had the potential to be complementary with CRP, especially in the context of investigating authentic, personally-relatable problems and engineering

solutions. This is further supported by the congruency between certain elements of a social constructivist approach to science and CRP, particularly regarding making science learning authentic, relevant, and meaningful, fostering discussion with the goal of sense-making, and taking advantage of the social nature of learning as empowered by a positive, supportive learning environment (Ladson-Billings, 1995; Grimberg & Gummer, 2013; NRC, 2012; Oldfather, 1993).

The need for specific training on CRP in the context of science inquiry teaching is highlighted given that the outcomes of this study identified an abundance of elements of both CRP and science inquiry in the classrooms, practices, attitudes, and beliefs of the participating teachers. The importance of CRP professional learning in particular is necessary when considering the intersection of science instruction and CRP. Nam, Roehrig, Kern, and Reynolds (2012) noted that teachers' feelings about CRP with regard to teaching science tend to fall into one of three categories. There are teachers who recognize the importance of creating a culturally relevant setting in which students are not only comfortable learning, but also where the teacher, in turn, learns from his or her students. These teachers already tend to engage in practices that reflect CRP. There are also teachers who recognize the importance of engaging in CRP in their science class, but do not have the experience or are unable to recognize the means by which to employ culturally relevant practices when teaching science. Finally, there are science teachers who do not see the need to engage in CRP when teaching science. These teachers are more likely to explain the lack of achievement on the students' inability or unwillingness to engage in the learning and consider that lack of engagement an artifact of the students' own cultural identities. Furthermore, these teachers are more likely to regard science as a

culturally neutral area of content, one that does not require engaging in CRP in order to effectively engage students from different cultural backgrounds. Supporting these distinctions, Johnson (2011) found that teachers trained in CRP are found to be more likely to recognize that their students are capable of achieving success, despite the differences between the students' cultural identities and the teacher's and/or school's cultural norms and values. They are also more likely to actively work to level the playing field with regard to opportunities to learn, recognize that students are responsible for knowledge construction, and to create a positive, inclusive classroom community build on a foundation of respect and relationships.

The outcomes of this study carry implications for how schools and school leaders may seek to identify exemplary teachers who can serve as models for other teachers similarly situated with regard to limited experiences and knowledge of science as well as teaching low SES populations. While not causative in nature, the outcomes of this study suggest that the common characteristics exhibited by Ashley, Miranda, and Tali likely play a significant role in the fostering of a positive science learning climate and the success of their students with regards to science performance outcomes. This study suggests that among teachers who exhibit these qualities, there is an awareness, even if an incomplete one, of the actions these teachers take and the impact they have on their approach to teaching science and fostering a positive science learning environment. Additionally, those tasked with supporting elementary science teaching and learning could use the outcomes of this study to identify exemplar teachers and teaching practices that could help place teachers in the positions and locations where they can have the greatest impact on the most vulnerable of learners. Significantly, these outcomes will

inform those who support elementary science teaching and learning of the nature of these qualities, including how successful teachers may not necessarily exhibit one narrowly define set of characteristics that can be attributed to the success of their students in learning science in low SES settings. School and district leaders would benefit from identifying teachers who routinely plan well-aligned science lessons that focus on knowledge building and conceptual understanding through sense-making science inquiry experiences. These should include the application of authentic SEPs, the use of questions to elicit ideas and probe understanding, the use of collaborative student discussions to foster sense-making, and the teaching through engaging with scientific phenomena where the emphasis is on constructing explanations and supporting reasoning through evidence and experience rather through direct instruction and a heavy reliance on text materials that passively impart information. Additionally, school leaders should identify teachers who exhibit a positive attitude towards both teaching science and towards their students as being potentially successful learners who are capable to achieving high expectations of performance in science. They should also look for a science rich, positive learning environment where discussion is routine and shows a valuing of student voice and where the teacher assumes the role of the facilitator of learning and not the sole knowledge authority.

Although the focus of this study was not on the impact of professional learning experiences, all three teachers shared a similar narrative regarding the impact of positive, meaningful PD on their feelings and classroom practices with regard to teaching science through an inquiry-based approach. The outcomes of this study suggest that such positive, relevant PD focused on inquiry-based science instructional practices can have a

positive impact on changing the practices of elementary teachers who might otherwise regard science with apprehension. Similarly, while curriculum was not a focus of this study either, the common elements evident across the practices of all three teachers suggest that the selection, support, and professional learning around elementary science curriculum resources should reflect an inquiry approach to science that includes not only opportunities for engaging in authentic science practices around developing an understanding of different scientific phenomena but also opportunities for students to engage in collaborative work and sense-making dialogue driven by teacher prompted discussion questions. The outcomes of this study not only carry implications for inservice PD, but also can help inform the focus of preservice elementary science teacher education programs. Future elementary teachers likely to enter districts and schools serving high numbers of SIP as well as teachers already working in such a setting would benefit from a program of study that simultaneously focused on both inquiry-driven instruction through authentic science practices and on an understanding of the impact of CRP practices. These should include sense-making strategies and inquiry practices where students learn through experiences and investigations whereby they directly engage with different scientific phenomena with the purpose of attempting to construct a conceptual understanding of science concepts and content knowledge that is reflected by the phenomenon (Kim & King, 2012; Passmore, Stewart, & Cartier, 2009; Wu & Hsieh, 2006). This would be in contrast to a more didactic approach to science learning where science content is present as concrete fact by the teacher and any experience or investigation serves the purpose of verifying memorized facts or function as little more than disconnected, meaningless hands-on activities without context or deeper learning

taking place (Akerson, et. al., 2009; Haefner & Zembal-Saul, 2004; Kim & King, 2012; NRC, 2012). Given the lack of comfort and familiarity many elementary teachers experience when it comes to science content and science inquiry teaching practices (Deniz & Akerson, 2013; Sandholtz & Ringstaff, 2013; Slavin, Lake, Hanley, & Thurston, 2014; Thomson & Kaufmann, 2013), such teacher development should also include a focus on building conceptual knowledge of science content through experiences that simultaneously build an understanding of and experience with science inquiry practices that reflect authentic SEPs.

At the same time, teacher development should couch these science learning experiences in a learning environment that models and unpacks the significance of different applicable elements of CRP. Through engaging in and learning about authentic science practices, teachers can also experience sense-making dialogue that serves as a way to value student voice and foster discussion and collaboration where their role in the classroom is modeled as that of the facilitator. There should also be a focus on the significance of communicating not only high expectations of student performance but also affirmation of student attainment of those expectations. Coursework on methods of engaging diverse student populations should be embedded in classes where teachers are able to see the way in which such methods are not only congruent with the science content learning taking place in the class, but also can be complementary to it (Brown, 2017). This should include not just the complementary nature of engaging students through the sense-making discussion and social interaction that comes with analyzing and interpreting data, constructing explanations, engaging in argumentation and reasoning, and developing and using models, but also the complementary nature of modeling and

supporting the routine use of science-specific academic vocabulary, not only as a means for students to develop an understanding of the terms that reflect the nature of science as a human endeavor, but also as a means of inviting students to become a part of the culture of science practices that is taking place in the classroom (Townsend, Brock, & Morrison, 2018).

Further Research.

While the current study illustrates that these three teachers all share a common set of characteristics with regard to their instructional practices, attitudes, beliefs, and student impact and that these shared traits were congruent with many of the defining qualities of science inquiry teaching and CRP, the nature of this study limits the degree to which these conclusions can be extrapolated in order to construct broad generalizations regarding the overarching impacts of how these teachers interact with their students in the context of elementary science teaching and learning. Therefore, this study serves not as a definitive statement on the best possible practices teachers should employ when teaching science to low SES elementary students but rather as a launching point from which to conduct additional research into the possible cause and effect relationships between individual practices, traits, attitudes, and beliefs and how these different factors impact the outcomes of elementary science performance among low SES students.

Another avenue of research would be to determine if those characteristics and practices not unique to science instruction were also evident in how these teachers teach other content areas they were responsible for, especially given the strong connection between inquiry-based science teaching and both math, through the collection, analysis, and interpreting of data, and ELA, through the sense-making practices of constructing

explanations, engaging in argumentation and reasoning, and obtaining and communicating information. Similarly, it would be worth investigating if the same success the low SES students of these teachers achieved with regard to science manifested in standardized assessments in math and ELA as well. It would also provide even greater insight into the possible significance of the practices observed among these three teachers if future studies compared the outcomes of this study by examining the practices, attitudes, and beliefs of teachers in similar settings but whose low SES students did not perform as well on the state's end of the year science standardized test. Finally, it would also be of benefit to examine the practices, attitudes, and beliefs of teachers who do not teach high numbers of low SES students to ascertain whether and to what degree elements of science inquiry practices and/or CRP might be present among those teachers.

ALTERNATE EXPLANATIONS AND LIMITATIONS

Alternate Explanations.

In considering the findings of this study, it is necessary to consider the possibility that factors other than the science rich classroom culture, the utilization of science inquiry practices, the elements of social constructivism, and the CRP employed these teachers might account for the previous student science achievement success as well as the positive elements evident with the current groups of students. It is possible that the outcomes of the 2016-2017 4th grade state science standardized test for the low SES students of these teachers were not the result of the observed and described factors evident with the current student groups. Students from the 2016-2017 school year might have simply been more adept at science for these teachers relative to the other low SES students in the school district. It is also possible that the students during the current

school year have come from a more science-rich background, accounting for their general positive attitudes towards learning science.

The researcher dismisses these alternate explanations, however, given the consistency of practices, attitudes, and beliefs displayed by all three teachers, despite teaching at three different schools and having varied degrees of teaching experience. Additionally, that these common characteristics are congruent with most of the research-supported characteristics of both effective science inquiry practices and CRP suggests that their presence was not a coincidence but rather the contributing factor to the success of their students. Finally, only twenty-one of the more than 210 4th and 5th grade teachers in the school district met the initial selection criteria of having 50% or more of their student qualifying for the NSLP while at the same time have the percentage of those students outperform the district percentage of low SES students who scored “Meets Expectations” or “Exceeds Expectations” on the 2016-2017 end of the year science assessment. It seems highly unlikely that the positive performance of low SES students of these teachers resulted from reasons other than those factors observed in the three participating teachers’ classroom.

Limitations.

The researcher acknowledges the following limitations regarding this study. The researcher’s positionality may have resulted in inaccurate or guarded responses to the interview and focus group questions. Furthermore, the voluntary and self-selected nature of the observed exemplar lessons could have resulted in the participants showcasing lessons that were intentionally designed to meet what they perceived as the researcher’s expectations as opposed to what is the norm in their classrooms. Although this may have

resulted in any inferences made from those data being called into question, the researcher did not detect any evidence to suggest that the participants were providing guarded or contrived responses or that what was observed in the classrooms was anything other than the genuine, routine science instruction that commonly took place with the students of these teachers. Furthermore, there is no evidence that the observed lessons were anything other than examples of the common place science teaching and instructional practices of these teachers. Had it not been so, there would have been evidence among the students that would have suggested that they were not used to the type of science instruction or the interactions they were engaged in with their teachers and one another. Additionally, the genuine responses from the focus groups supports the assertion that what was observed was the norm as it aligned with the descriptions the students conveyed regarding their perceptions of learning science from these teachers.

Additional limitations are related to the means and frequency of the instructional practices data collection. Although the nine observations revealed an abundance of data, had additional observations been conducted, it is possible that the trends and patterns observed may have been further reinforced or changed if additional practices and characteristics had been observed. The nature of the IPL-S is also subject to limitations. Although participants were given guidance and supporting materials on its use, the classification of self-reported practices is somewhat subjective in nature.

It is also important to note that with a possible nineteen 4th and 5th grade teachers who met the selection criteria and who still taught science during the 2017-2018 school year, that had different participants been selected, characteristics might have been observed that differed significantly from those of the three participants. There is also a

limit to how far one can extrapolate from the data regarding the broader implications of the study's findings given that the data were collected from only three participants over the course of three observations each. Had other lessons been observed or had more observations occurred, it is possible that the outcomes may have been different. At the same time, additional observations may have served to strength the researcher's conclusions by providing addition evidence of the practices, attitudes, and beliefs observed from the three participants and their students.

Despite these limitations and possible alternate explanations, the researcher is confident that the descriptions of observed practices, attitudes, and beliefs are valid and that the inferences regarding their alignment to the characteristics of science inquiry teaching practices and CRP are accurate. This confidence is based on the consistency of data collection methods the researcher engaged in, the degree of data saturation based on the number of observations, the congruence between the observed behaviors and the attitudes and beliefs described by the teachers themselves, the congruence between the observed practices and the reporting of science activities on the IPL-S, and the support of the member checking feedback. This confidence if bolstered by the occurrence of the expected impact of these teachers' practices, attitudes, and beliefs on the students' own feelings and attitudes towards learning science and their teachers.

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APPENDIX A

DESCRIPTIVE OBSERVATION FRAMEWORK

Figure A.1 presents the descriptive observations framework that was used by the researcher to code the occurrence of possible science inquiry teaching elements and culturally relevant pedagogical elements that might have been evidence during the descriptive analysis of the classroom observations. The purpose of the descriptive observation framework is to provide the researcher with a set of descriptive characteristics to help in identifying and coding the occurrence of different instructional practices and elements that might be presenting during a given observation. This way, the research will be consistent in making notes in the field journal as well as during the video analysis that follows the observations.

Given the qualitative nature of these observations, this framework is not intended to be an absolute, rigid set of criteria and it is expected that some elements of a given practice might not be present while other elements would. Additional details and clarifications about the occurrence of an element would be provided by the researcher's field notes taken at the time of the observation as well as from the video analysis that follows. Additionally, the coding of an element is not intended to convey a sense of quality or provide a scale of performance regarding the element as those details will be provided from the field notes and the post observation analysis.

Code	Description of Instructional Practices/Elements	Occurrence
QU	1. There is evidence that investigations, problems, and/or explorations are driven by scientifically testable questions. 2. Students show evidence they understand that they are collecting data (observations and/or measurements) to answer a question.	
IN	1. Students are engaged in teacher-planned scientific investigations or explorations for the purpose of generating data. 2. Students are engaged in student-planned scientific investigations or explorations for the purpose of generating data.	
DA	1. Students are organizing data, either generated by students or provided by the teacher, using charts, graphs or other organizing mechanisms. 2. Students are discussing the data and using it to make and support inferences and claims.	
EX	1. Students are using data to construct their own explanations of processes and/or phenomena. 2. Students are connecting data with prior knowledge to describe a cause and effect relationship.	
CO	1. Students are communicating (verbally, written, visually) their knowledge, claims, inferences, or explanations about processes/phenomena. 2. Student communications show evidence of connecting data with reasoning to support claims, inferences, or explanations.	
MO	1. Students develop their own conceptual models of scientific phenomena or processes. 2. Students use models (their own or teacher provided) to describe or explain phenomena/processes.	
HX	1. Teacher provides positive verbal encouragement to students during science. 2. Classroom exhibits positive messages regarding student capabilities. 3. Teacher communicates in a positive manner that students are capable of being successful in their science learning.	
SC	1. Students are the ones primarily speaking and sharing ideas. 2. Ideas, claims, explanations are generated by students. 3. Students assume the role of peer teachers. 4. Teacher assumes role of guide and/or support in the learning experience.	
KB	1. Student work and outcomes are the primary source of new knowledge. 2. New knowledge is examined in the context of prior knowledge and/or knowledge from informational sources (textbooks, videos, readings, etc...).	
FL	1. There is evidence that the teacher is aware of his/her student characteristics. 2. Teacher changes the learning experience (teacher actions, available resources, student work) as needed, on an individual, small group, or whole class basis, based on (formative and/or summative) assessment data.	
CX	1. Science learning experience includes contextual elements that are personally relevant and/or culturally meaningful and familiar to the students. 2. Teacher-student interactions show evidence that student voice and identity an important part of the learning experience.	
SJ	1. Learning is situated in a context that represents a need or problem personally relevant to the cultural identities of the students. 2. Students and student work assume a role of advocacy in communicating the problem or need and solution to members of the students' community.	

Figure A.1 Descriptive Observational Framework

APPENDIX B

DESCRIPTION OF IPL-S

Instructional Practices Log for Science (IPL-S) directions for use.

(reprinted from the *User's Guide: Instructional Log for Mathematics and Science*. Project ATOMS. North Carolina State University. 31-32)

Permission to reprint this excerpt granted by Dr. Temple Walkowiak, Principle Investigator of Project ATOMS via email on April 29th, 2018.

The “Target Class”

You will select a “target class” for logging if you teach more than one class of students for science. Across all 45 days of logging, you will use this same class of students as your reference. This class may or may not be the same group of students as your “target class” for science logging.

The “target class” should be your class that receives your typical science instruction. By “typical science instruction,” we mean that which best represents your science instruction across the school year.

Section and Scales

The science log is divided into four sections:

(1) Content, Time, and Goals This section of the log asks you about the content focus of your science instruction, how much time your students spend on science, and the learning goals for your science instruction.

In this section of the log, there is one scale for the item that states, “To what extent was each of the following topics a focus of today’s science instruction with the target class?” The scale is outlined and described below:

Not today: The topic was not taught today.

Secondary focus: The topic was a focus of instruction for the students in the target class, but it was not a primary emphasis or your main teaching objective. Instruction or practice in this topic area might have been a smaller feature of the lesson or a support of your teaching in the area(s) of major focus.

Your secondary focus might have been directly related to your primary focus, or it might have been another area. For example, the primary focus of your instruction might have been the structure of plants, but you might have asked the target class to look at fossils of plants to study the change. Or, you might have focused primarily on the water cycle, but you spent some time discussing how landforms can impact the water cycle.

Typically, less of your instructional time would be spent on areas that you

consider a secondary focus. You might have more than one area of secondary focus on a given day.

Primary focus: The topic was a main emphasis or a primary teaching objective in the science instruction experienced by the students in the target class. You might have more than one area of primary focus on a given day. The primary focus for the day might have been new material that you were introducing, or it might have been review or practice to which you devoted a large percentage of the science instruction.

(2) *Teacher Tools:* This section of the log asks you to provide information about the tools you used during science instruction.

(3) *Student Activities:* This section of the log contains the most items and focuses on how much time the students in the target class spend on various activities.

In this section of the science log, there is one scale for every item. Every item has the same question stem, “During today’s science instruction, how much time did the students in the target class,” followed by an activity. The scale for this section is outlined and described below.

Not today: The item was not done during today’s science instruction by the students in the target class.

Little: The item made up a relatively small part of today's science instruction for students in the target class.

Moderate: The item made up a large portion, but NOT the majority of today's science instruction for students in the target class.

Considerable: The item made up the majority of today's science instruction for students in the target class.

(4) *Non-Science Days:* This section of the log asks you what students did instead of science on non-science instructional days.

Instructional Practices Log for Science (IPL-S) items.

(from the *User's Guide: Instructional Log for Mathematics and Science*. Project ATOMS. North Carolina State University. 33-36)

Permission to reprint this excerpt granted by Dr. Temple Walkowiak, Principle Investigator of Project ATOMS via email on April 29th, 2018.

Section 1: Content, Time, and Goals

Did YOU teach science today?

To what extent did your science instruction today focus on each of the following science topics with the target class?

Matter (e.g., solid, liquid, gas, plasma)

Force and Motion (e.g., speed, gravity, magnetic force)

Energy (e.g., sunlight, electricity, energy transfer)

Sound, Heat, or Light Waves (e.g., vibration, wavelength, color)

Plants and Animals (e.g., survival, life cycle, behavior, reproduction, human body, cells)

Ecosystems (e.g., habitats, food webs, decomposition)

Heredity (e.g., genes, inherited traits)

Evolution (e.g., fossils, adaptations)

Solar System (e.g., the sky, moon phases, planets)

The Earth (e.g., wind, water, rocks, landforms, weather, erosion, plate tectonics, seasons, geologic hazards)

Environment (e.g., natural resources, sustainability, Earth's systems)

Other

How many total minutes did you and the students in the target class spend on the science topic(s) specified above? Please include only science instruction for which you were the teacher.

To what extent were the GOALS of today's science instruction for students in the target class to:

Learn about the relevance of science to society

Develop test taking skills

Connect scientific concepts (e.g. systems, cycles, patterns) to everyday life

Apply science to real world problems

Develop laboratory skills and techniques

Understand the scientific method

Develop children's interest in science

Practice science safely

Cooperate with others

Develop reading comprehension skills

Develop scientific writing skills

Observe patterns in science

Identify cause and effect in scientific phenomena

Identify differences and similarities in scientific phenomena

Make inferences based on scientific knowledge or data

Section 2: Teacher Tools

What did YOU use during science instruction?

Science Kits

Scientific objects or specimens

Photographs related to science ideas

Diagrams of science ideas

Scientific computer simulations

Videos or video clips about science ideas

Science non-fiction trade books (e.g., All About the Weather, Bats!)

Science fiction trade books (e.g., The Very Hungry Caterpillar, Who Sank the Boat)

Online or print science encyclopedias

Science newspapers or magazines

Science textbooks

None of the Above

Section 3: Student activities

During today's science instruction, how much time did the students in the target class:

Listen to the teacher explain science concepts

Read or listen to science reading

Go outside to learn about science

Complete science worksheets

Take a science test or quiz

Take science notes

Conduct a hands-on activity or manipulate materials

Watch a science video or video clip

Present or watch other students present oral science reports

Use science related internet resources or software

Play a science game

Watch a science demonstration (e.g., teacher is showing a science experiment to the class)

Write about or illustrate science ideas

Discuss science ideas

Explicitly connect today's learning to their prior knowledge

Explain their thinking to see if they are "getting it"

Recall information from previous lessons

Use overarching concepts (e.g., systems, cycles, patterns) to draw connections between different science topics (e.g., matter, ecosystems, the Earth)

Support their thinking with evidence (e.g., observations, measurements)

Compare multiple explanations of a science idea

Share scientific explanations with other students

Examine scientific claims made by others

Evaluate the quality or performance of a design

Communicate information using models, drawings, writing or numbers

Formulate scientific questions

Make predictions to forecast future events

Generate hypotheses based on scientific facts

Follow appropriate steps in an activity

Examine scientific objects or specimens

Make observations

Test a hypothesis using more than one trial

Manipulate a variable in an experiment

Use tools or instruments (e.g., rulers, balances, thermometers, graduated cylinders, telescopes, microscopes)

Take measurements

Record data

Display data in tables or graphs

Research a science topic

Learn science vocabulary or scientific facts

Organize or record scientific information

Compare predictions to findings

Develop a plan to test a hypothesis

Summarize learning about a science idea

Use results to address a scientific question

Create neat and organized products

Build physical models or representations

Create simulations (e.g., animated computer graphics or acting out a science phenomenon)

Make drawings or diagrams

Label parts of objects, cycles, or systems

Section 4: Non-Science Days

Please select the reason the YOU did NOT teach science today.

I had planned to teach science today, but I needed more time for other content areas.

A substitute teacher taught today.

Today was an early release or late start day.

I had another subject area or activity scheduled today.

Someone else teaches science to this class (e.g., team teaching).

My students had science special today with our school science specialist.

My students had a field trip, assembly, or classroom visitor.

Other

What did your students do today during the time block that you normally teach science?

Math

Literacy

Computer Lab

Social Studies

Intervention or enrichment

Other

APPENDIX C

CONSENT AND PRIVACY FORMS

On the following pages, the following forms are reproduced as they were originally distributed to participating teachers to use with their students:

- Teacher Participant Informed Consent Form
- Parent Letter and Permission Form
- Student Assent Form
- Spanish Language Translations of Parent and Student Forms

UNIVERSITY OF SOUTH CAROLINA

CONSENT TO BE A RESEARCH SUBJECT

PRACTICES, PEDAGOGY, AND INSTRUCTIONAL BELIEFS OF SUCCESSFUL ELEMENTARY SCIENCE TEACHERS IN LOW SES SCHOOLS

PURPOSE AND BACKGROUND:

You are being asked to volunteer for a research study conducted by Ed Emmer. I am a doctoral candidate in the Department of Teaching and Learning, at the University of South Carolina. The University of South Carolina, Department of Teaching and Learning is sponsoring this research study. The purpose of this study is to determine what instructional practices and pedagogical approaches are being employed in the classes of selected teachers. Targeted teachers work in schools serving low SES neighborhoods and with students who are performing above the average when compared with other students identified as living in poverty. You are being asked to participate in this study because you have been identified as meeting these criteria. This study is being done at three schools, and will involve approximately three teacher volunteers. This form explains what you will be asked to do, if you decide to participate in this study. Please read it carefully and feel free to ask questions before you make a decision about participating.

PROCEDURES:

If you agree to be in this study, the following will happen:

1. You will be asked to identify at least three model lessons that showcase your science inquiry teaching skills and practices. These lessons will be observed and video recorded by the principal investigator.
2. You will be asked to complete an interview following the completion of all three observations about your experiences, ideas, and beliefs regarding science teaching and learning. This interview will be audio recorded in order to ensure the details that you provide are accurately captured.
3. You will be asked to complete a daily digital instructional practices log for science for the purposes of recording the various elements of science instruction that occur in your class on a daily basis during a 45 day period.

DURATION:

Participation in the study will take three classroom observation visits and one post observation interview over a period of three months. Each study visit will last the duration of the science lesson being observed.

RISKS/DISCOMFORTS:

Loss of Confidentiality:

There is the risk of a breach of confidentiality, despite the steps that will be taken to protect your identity. Specific safeguards to protect confidentiality are described in a separate section of this document.

BENEFITS:

This research may help researchers understand how elementary teachers can help their students living in poverty reduce the science achievement gap. Additionally, by identifying and analyzing specific practices you employ, you will benefit from a greater understanding of why those practices are effective at helping reduce the science achievement gap.

COSTS:

There will be no costs to you for participating in this study.

PAYMENT TO PARTICIPANTS:

You will not be paid for participating in this study.

CONFIDENTIALITY OF RECORDS:

Unless required by law, information that is obtained in connection with this research study will remain confidential. Any information disclosed would be with your express written permission. Study information will be securely stored in locked files and on password-protected computers. Results of this research study may be published or presented at seminars; however, the report(s) or presentation(s) will not include your name or other identifying information about you. Where necessary, pseudonyms will be used in place of actual names.

VOLUNTARY PARTICIPATION:

Participation in this research study is voluntary. You are free not to participate, or to stop participating at any time, for any reason without negative consequences. In the event that you do withdraw from this study, the information you have already provided will be kept in a confidential manner. If you wish to withdraw from the study, please call or email the principal investigator listed on this form.

I have been given a chance to ask questions about this research study. These questions have been answered to my satisfaction. If I have any more questions about my participation in this study, or a study related injury, I am to contact Ed Emmer at (803) 609-2081 or email eemmer@richland2.org.

Questions about your rights as a research subject are to be directed to, Lisa Johnson, Assistant Director, Office of Research Compliance, University of South Carolina, 1600 Hampton Street, Suite 414D, Columbia, SC 29208, phone: (803) 777-7095 or email: LisaJ@mailbox.sc.edu.

I agree to participate in this study. I have been given a copy of this form for my own records.

If you wish to participate, you should sign below.

Signature of Subject / Participant

Date

Signature of Qualified Person Obtaining Consent

Date



January 29, 2018

Dear Student and Parent/Guardian:

Your child's teacher is working with a doctoral student at the University of South Carolina as part of a study of effective science teaching practices in elementary schools serving low socioeconomic neighborhoods. Your child's teacher has been identified for this study based on the success of her students in learning science.

In order to gain an understanding of the teaching practices employed by your child's teacher, information regarding typical classroom practices will be collected through three different observations. These observations will be conducted and video recorded by the principal investigator.

At the conclusion of these observations a select group of students will be invited to participate in a focus group interview where they will be given a chance to share their ideas and experiences regarding learning science. Student responses to the focus group questions will not be shared with your child's teacher.

In order to maintain confidentiality of all participants in this study, **we will keep the teacher's and students' names and identities confidential at all times.** The collected information will be used for the purpose of describing and analyzing the impact of the teaching practices being used in your child's science class. Results of this research study may be published or presented at seminars; however, the report(s) or presentation(s) will not include your child's name or other identifying information about your child. Where necessary, pseudonyms will be used in place of actual names.

Participation in the program is voluntary, and your child may withdraw from the program at any time. We ask that you make this clear by completing the attached signature form. On behalf of all of the partners involved in this program, I want to thank you for your assistance. If you have any questions, please contact your child's teacher and/or the principal investigator Ed Emmer, K-5 Science Content Specialist for Richland School District Two by phone at 803-609-2081 or by e-mail at eemmer@richland2.org

Thank you for your assistance,

Ed Emmer
K-5 Science Content Specialist
Richland School District Two
763 Fashion Drive
Columbia, SC 29229

Please check the appropriate space, sign your name, and enter the date. Please have your child return this portion of the letter to his/her teacher by the following

Due date: _____

Once again thank you.

Permission to participate in video recorded classroom observations

Please check <u>one</u> of the two options below:	Participation in recorded classroom observations (no one but the principal investigator will view video recordings)
<p>_____</p> <p>Check here</p>	<p>I give my permission for my child to take part in the documentation efforts of the science teaching practices employed by my child's teacher as part of a USC doctoral research study. The documentation efforts include classroom observations and videotaping of science lessons.</p>
<p>_____</p> <p>Check here</p>	<p>I DO NOT give my permission for my child to take part in the documentation efforts of the science teaching practices employed by my child's teacher as part of a USC doctoral research study.</p>

Permission to participate in audio recorded focus group interview

Please check <u>one</u> of the two options below:	Participation in recorded focus group interview (no one but the principal investigator will review audio recordings)
<p>_____</p> <p>Check here</p>	<p>I give my permission for my child, if invited, to take part in a focus group interview as part of an effort to gather information about how the students in my child's science class feel about learning science. I understand the focus group interview will be audio recorded and that specific information from the focus group interview will not be shared with my child's teacher.</p>
<p>_____</p> <p>Check here</p>	<p>I DO NOT give my permission for my child to take part in the focus group interview process as part of a USC doctoral research study.</p>

Signature, Parent/Guardian

Date

Signature, Student

Students Name (Printed)

UNIVERSITY OF SOUTH CAROLINA
ASSENT TO BE A RESEARCH SUBJECT

Study Title: Practices, Pedagogy, and Instructional Beliefs of Successful Elementary Science Teachers in Low SES Schools.

I am a researcher from the University of South Carolina. I am interested in learning about teachers who are very good at teaching science in 4th and 5th grade and I would like your help. I would like to learn more about how your teacher teaches you science and how you feel about learning science in your class. Your parent/guardian knows that I want to learn about how your teacher teaches science, but it is up to you if you want to be a part of this study.

If you are interested in helping me with this study, here is what you can expect:

I will be in your class at three different times to watch your teacher teach and watch your class learn science. I will also be recording videos when I am here. During these visits, all you need to do is what you normally do when your teacher is teaching science.

After my visits, I may be asking you and some of your classmates to answer some questions about what it is like learning science with your teacher. This talk will take about 30 minutes and will take place at your school in a conference room. I will also be recording these group meetings.

Any information you share with me will be private. No one except me will know what your answers to the questions are.

If you do not want to be a part of this, that is alright. This is not related to your regular science class and will not help or hurt your grades in any way. You can also drop out of the study at any time, for any reason, and you will not be in any trouble and no one will be mad at you.

Please ask any questions you would like to about the study.

Thank you and I look forward to visiting your class.

Ed Emmer
Doctoral Student
University of South Carolina

UNIVERSIDAD DE CAROLINA DEL SUR

CONSENTIMIENTO PARA SER SUJETO EN UNA INVESTIGACIÓN

Título del estudio: Prácticas, pedagogía y creencias instructivas de los maestros exitosos de ciencias en la escuelas elementarias SES.

Soy un investigador de la Universidad de Carolina del Sur. Estoy interesado en aprender sobre maestros que son muy buenos para enseñar ciencias en 4to y 5to grado y quisiera contar con tu ayuda. Me gustaría aprender más sobre cómo tu maestro te enseña ciencias y cómo te sientes acerca de aprender ciencias en la clase de él. Tu padre / madre / tutor sabe que quiero saber cómo tu maestro te enseña ciencias, pero depende de ti si quieres ser parte de este estudio.

Si estas interesado en ayudarme con mi estudio, esto es lo que va a suceder:

Estaré en tu clase en tres momentos diferentes para ver a tu maestro(a) enseñar y ver como tu clase aprende ciencias. También grabaré videos cuando yo esté aquí. Durante estas visitas, todo lo que necesita hacer es lo mismo que normalmente haces cuando tu maestro está enseñando la clase de ciencias.

Después de mis visitas, podria pedirte a ti y a algunos de tus compañeros de clase que respondan algunas preguntas sobre cómo es aprender ciencias con tu profesor. Esta charla durará aproximadamente 30 minutos y tendrá lugar en la sala de conferencias de tu escuela. También grabaré estas reuniones grupales.

Cualquier información que compartas conmigo será privada. Nadie excepto yo sabrá cuáles son tus respuestas a las preguntas.

Si no quieres ser parte de esto, está bien. Esto no está relacionado con tu clase de ciencias y no te ayudarán ni te perjudicarán en tus calificaciones. También puedes abandonar el estudio en cualquier momento y por cualquier motivo, y no estarás en problemas y nadie se enojara contigo.

Por favor, pregunta lo que quieras sobre este estudio

Gracias y espero visitar su clase.

Ed Emmer
Estudiante de doctorado
Universidad de Carolina del Sur



29 de enero de 2018

Estimado alumno y padre / tutor:

El maestro de su hijo está trabajando con un estudiante de doctorado en la Universidad de Carolina del Sur como parte de un estudio de prácticas efectivas de enseñanza de ciencias en escuelas primarias que prestan servicios a vecindarios de bajo nivel socioeconómico. El maestro de su hijo ha sido elegido para este estudio basado en el éxito de sus estudiantes en el aprendizaje de ciencias.

Con el fin de obtener una mayor comprensión de las prácticas de enseñanza empleadas por el maestro de su hijo, se recogerá información sobre las prácticas habituales de la clase a través de tres observaciones diferentes. Estas observaciones serán conducidas y grabadas en video por el investigador principal.

Al concluir estas observaciones, un grupo selecto de estudiantes será invitado a participar en una entrevista grupal donde se les dará la oportunidad de compartir sus ideas y experiencias con respecto al aprendizaje de ciencias. Las respuestas de los estudiantes a las preguntas del grupo investigador no se compartirán con el maestro de su hijo.

Para mantener la confidencialidad de todos los participantes en este estudio, **mantendremos en todo momento los nombres e identidades de los estudiantes bajo absoluta confidencialidad.** La información recopilada se usará con el propósito de describir y analizar el impacto de las prácticas de enseñanza que se usan en la clase de ciencias de su hijo. Los resultados de este estudio de investigación pueden publicarse o presentarse en seminarios; sin embargo, el (los) informe (s) o presentación (es) no incluirán el nombre de su hijo u otra información de identificación acerca de su hijo. Y si es el caso, se usarán seudónimos en lugar de los nombres reales.

La participación en el programa es voluntaria y su hijo puede retirarse del programa en cualquier momento. Para tener claridad, Le pedimos que complete el formulario adjunto y lo firme. En nombre de todos los que participamos en este programa, quiero agradecerles por su ayuda. Si tiene preguntas, Por favor comuníquese con el maestro de su hijo y el Director investigador Ed Emmer, Especialista de Contenido de ciencias de los grados K-5 para el Distrito Escolar Richland Dos al teléfono 803-609-2081 o por correo electrónico a eemmer@richland2.org

Gracias por su asistencia,

Ed Emmer
Especialista en contenido de ciencias K-5
Distrito Escolar Richland Dos
763 Fashion Drive Columbia, SC 29229

Verifique el espacio apropiado, firme su nombre e ingrese la fecha. Por favor Haga que su hijo devuelva esta parte de la carta a su maestro(a)

para el día: _____

Una vez más, Gracias.

Permiso para participar en observaciones del salón de clase que serán grabadas

Marque una de las dos opciones a continuación:	Participación en las observaciones grabadas en el aula (nadie más que el investigador principal verá las grabaciones de video)
_____ Marque Aquí	Doy mi permiso para que mi hijo participe en los esfuerzos de documentación de las prácticas de enseñanza de ciencias utilizadas por el maestro de mi hijo como parte de un estudio de investigación doctoral de la USC. Los esfuerzos de documentación incluyen observaciones en el aula y grabación de video de las lecciones de ciencias.
_____ Marque Aquí	NO DOY mi permiso para que mi hijo participe en los esfuerzos de documentación de las prácticas de enseñanza de ciencias empleadas por el maestro de mi hijo como parte de un estudio de investigación doctoral de la USC.

Permiso para participar en la entrevista grupal de audio que sera grabada

Marque una de las dos opciones a continuación:	Participación en la entrevista del grupo de investigacion que sera grabado (nadie más que el investigador principal revisará las grabaciones de audio)
_____ Marque Aquí	Doy mi permiso para que mi hijo, si es invitado, participe en una entrevista grupal como parte de un esfuerzo para reunir información sobre cómo los estudiantes de la clase de ciencias de mi hijo piensan sobre el aprendizaje de la ciencia. Entiendo que la entrevista del grupo focal se grabará en audio y que la información específica de la entrevista del grupo focal no se compartirá con el maestro de mi hijo.
_____ Marque Aquí	NO DOY mi permiso para que mi hijo participe en el proceso de entrevistas grupales como parte de un estudio de investigación doctoral de la USC.

Firma del padre / tutor

Fecha

Firma del estudiante

Nombre en imprenta de los estudiantes