EXPLORING MULTILITERACIES, STUDENT VOICE, AND SCIENTIFIC PRACTICES IN TWO ELEMENTARY CLASSROOMS

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This study explored the voices of children in a changing world with evolving needs and new opportunities. The workplaces of rapidly moving capitalist societies value creativity, collaboration, and critical thinking skills which are of growing importance and manifesting themselves in modern K-12 science classroom cultures (Gee, 2000; New London Group, 2000). This study explored issues of multiliteracies and student voice set within the context of teaching and learning in 4th and 5th grade science classrooms. The purpose of the study was to ascertain what and how multiliteracies and scientific practices (NGSS Lead States, 2013c) are implemented, explore how multiliteracies influence students’ voices, and investigate teacher and student perceptions of multiliteracies, student voice, and scientific practices.

Grounded in a constructivist framework, a multiple case study was employed in two elementary classrooms. Through observations, student focus groups and interviews, and teacher interviews, a detailed narrative was created to describe a range of multiliteracies, student voice, and scientific practices that occurred with the science classroom context. Using grounded theory analysis, data were coded and analyzed to reveal emergent themes.

Data analysis revealed that these two classrooms were enriched with multiliteracies that serve metaphorically as breeding grounds for student voice. In the modern classroom, defined as a space where information is instantly accessible through the Internet, multiliteracies can be developed through inquiry-based, collaborative, and technology-rich experiences. Scientific literacy, cultivated through student communication and collaboration, is arguably a multiliteracy
that has not been considered in the literature, and should be, as an integral component of overall individual literacy in the 21st century. Findings revealed four themes. Three themes suggest that teachers address several modes of multiliteracies in science, but identify barriers to integrating multiliteracies and scientific practices into science teaching. The issues include time, increased standards accountability, and lack of comfort with effective integration of technology. The fourth theme revealed that students have the ability to shape and define their learning while supporting other voices through collaborative science experiences.
DEDICATION

This dissertation is dedicated to my husband, Matt, for offering unwavering support throughout this process. For five years he has read every word, asked the right questions, and offered the most perfect, encouraging words. I am forever grateful for his selflessness, support, and understanding.
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CHAPTER 1—INTRODUCTION

Overview

We left the boxes in the village. Closed. Taped shut. No instruction, no human being. I thought, the kids will play with the boxes! Within four minutes, one kid not only opened the box, but found the on/off switch. He'd never seen an on/off switch. He powered it up. Within five days, they were using 47 apps per child per day. Within two weeks, they were singing ABC songs [in English] in the village. And within five months, they had hacked Android. Some idiot in our organization or in the Media Lab had disabled the camera! And they figured out it had a camera, and they hacked Android. (Ackerman, 2012).

The above statement was made by One Laptop Per Child (OLPC) founder Nicholas Negroponte at the MIT Technology Review’s Emerging Technology conference in October, 2012. The “kids” he referred to were children of two tribes in Ethiopia, a country with a literacy rate of approximately 39% (CIA, 2013).

Although fascinating, this research study is not about whether or not children are innately “wired” to easily figure out and apply technology in their lives as demonstrated above. However, this study is about children in a changing world with evolving needs and new opportunities. The workplace of the new, rapidly moving capitalist society values creativity, collaboration, and
critical thinking (Smith, Mikulecky, Kibby, Dreher, & Dole, 2000)—skills which are of growing importance and are manifesting themselves in modern K-12 science classroom cultures.

Innovations in technology, particularly the Internet and mobile devices, have created unique opportunities for students to not only interact with information, but to communicate with other individuals as well. Interactions such as these require an evolving view of literacy in the classroom. In other words, students are not only engaged with contemporary technologies, but use them to employ new ways of thinking and interacting with the world—multiliteracies (Cope & Kalantzis, 2009; Lankshear & Knobel, 2006). This study explores issues of multiliteracies as well as student voice set within the context of teaching and learning science and in particular scientific practices in the elementary science classroom.

**Multiliteracies**

Multiliteracies emerged as a concept in 1994 when a small group of scholars met in New London to discuss a difficult question: “What constitutes appropriate literacy teaching in the context of the ever more critical factors of local diversity and global connectedness?” (Cope & Kalantzis, 2000, p. 3). This soon to be named New London Group understood the impact of “the changing world and the new demands being placed upon people as makers of meaning in changing workplaces, as citizens in changing public spaces and in the changing dimensions of our community lives—our lifeworlds” (Cope & Kalantzis, 2000, p. 4). Thus, the term “multiliteracies” was born. The “multi” in multiliteracies emerged from two views of literacy as “multiple.” First, innovations in technology change the use of text and communication in a variety of ways that expand beyond traditional literacy skills. Second, societies are now more linguistically and culturally diverse. Thus, the cultures of classrooms are not homogenous, as students represent varying cultures, languages, religions, and socioeconomic statuses
contributing to the need of and recognition of multiliteracies. Evidence of multiliteracies in the classroom include, but are not limited to, technology use, collaboration with peers and others (e.g. teacher, parents, administration, community members), problem solving, visual literacy, or a combination of communication or text modes (multimodality) (Cope & Kalantzis, 2000; Gee, 2000; Lankshear & Knobel, 2006).

Often associated with multiliteracies is the concept of new literacies, although the terms are not interchangeable. Cervetti, Damico, and Pearson (2006) explain that “discussions of new literacies tend to involve new technologies, while discussions of multiple literacies tend to involve many literacies and modalities beyond print literacy and a heightened awareness of culture” (p. 379). Although technology is increasingly influential in classrooms, multiliteracies are not limited to merely the use of technological tools, but rather the skills in communication and thinking that are necessary because of increasing use of new technologies. “In other words, the potential held by these technologies imply a radical social change, a redistribution of semiotic power, and the power to make and disseminate meanings” (Kress, 2003, p. 17). The “social change” referenced by Kress (2003) is not only in society at large, but in the microcosms of K-12 classrooms as well. In elementary science education, multiliteracies play an increasingly important role by enabling new ways for students to interact not only with science content and scientific practices, but with each other, the teacher, and the larger global community as well. As such, multiliteracies by description are value-laden embracing an individual’s integration of creativity, independent thinking, collaboration, and views of diversity.
Student Voice

“If school is about what students know, value, and care about, we need to know who students really are” (Dahl, 1995, p. 124). Student voice is more than the mere act of listening to students, however. All students have a voice but the concept of “student voice” implies that others value and respect the ideas of students as communicated orally, through writing/visuals, or even through silence (Cook-Sather, 2006). To know our students and how teaching and learning is relevant to their lives, Lincoln (1995) argues that “teachers must be willing to share power in the classroom” (p. 90). Although addressed almost two decades ago by Oldfather (1995), and perhaps more relevant today with multiliteracies, “learning from student voices—in the fullest sense—requires major shifts on the part of teachers, students, and researchers in relationships and in the ways of thinking and feeling about the issues of knowledge, language, power, and self” (p. 87).

If a shift in power is to occur in classrooms, then teachers must be critically aware of their own values and beliefs (Wade, 1995). Student empowerment (social, academic, and political) requires a classroom climate that is conducive to sharing and valuing diverse people and their ways of thinking (Dimick, 2012). This type of classroom climate requires that teachers give deliberate attention to the institutional power present in schools. Although complex and constantly evolving, the impact of institutional power must be analyzed in order to break down barriers to student voice and student empowerment (Robinson & Robinson, 2013).

As multiliteracies and scientific literacy continue to evolve in science education, student voice must be acknowledged as an area of focus. Multiliteracies attend to students’ roles in the classroom culture and society at large, as innovations in technology have made participating in
the global community accessible to most people—including elementary students. Students’ voices, then, can be “heard” and attended to in new ways that were not possible in the past. Through the use of internet technology, students are no longer just one voice in a classroom, but they have the possibility to be a voice heard around the world. With this new found communication comes great responsibility, both for the teacher and students.

Student voice arose as an educational research agenda in the early 1990s, but has since lost momentum as the decade ended. This study addresses student voice again, as the educational climate of the United States has evolved, progressively in some ways (e.g. multiliteracies) and regressively in others (e.g. high-stakes testing). Although addressing student voice is sometimes challenging because of issues of power and communication, failing to do so confines or even oppresses students in an educational system created and executed solely by dominant adult culture (Cook-Sather, 2006; Kvale & Brinkmann, 2009; Parnell & Patsarika, 2011). Foucault (1980) states that individuals are “always in the position of simultaneously undergoing and exercising […] power” (p. 98). Students are constantly negotiating their role in such power struggles, whether with the teacher, their peers, or a number of other outside forces. The Next Generation Science Standards (NGSS) (NGSS Lead States, 2013i), written by a team of 41 “experts,” including classroom teachers (in-service and retired), professors, and curriculum specialists is such an example of an outside force with no mention of student input during the development process. In creating a framework of performance objectives, it may have been beneficial to include student voice in the process as a source of insight into the relevancy of the standards to students’ lives. Because of their absence in previous curriculum and standards planning, analyzing the impact of multiliteracies on voice and scientific practices from the
perspective of students will give invaluable insight into the thinking of the most important stakeholders in education—students.

**Scientific and Engineering Practices**

Recently published online, the NGSS (NGSS Lead States, 2013i), written with overwhelming influence from The *Framework for K-12 Science Education (Framework)* (NRC, 2012), consists of three dimensions: science and engineering practices, crosscutting concepts, and disciplinary core ideas (NGSS Lead States, 2013i). Because this study’s focus is on science and scientific practices, below is a list of the scientific and engineering practices described in the NGSS, along with a short explanation of each practice.

*Asking questions (for science) and defining problems (for engineering).* Students should be able to ask questions for investigation as a result of reading texts, conducting observations, and participating in classroom discussion (NGSS Lead States, 2013c, p. 4-5).

*Developing and using models.* Models can be used as an instructional tool or created by students in order to represent their conceptualizations or explain a phenomenon (NGSS Lead States, 2013c, p. 6).

*Planning and carrying out investigations.* Students should participate in and design investigative activities that range from teacher-directed to full inquiry (NGSS Lead States, 2013c, p. 7).

*Analyzing and interpreting data.* Data in the science classroom can be organized and used to reveal patterns that can be communicated to others (NGSS Lead States, 2013c, p. 9).
Using mathematics and computational thinking. Conducting and analyzing measurements, numerical data, and graphs should be emphasized as a practice that enhances investigations and scientific arguments (NGSS Lead States, 2013c, p. 10).

Constructing explanations (for science) and designing solutions (for engineering). Through the use of the other practices, students should be able to use evidence to explain phenomena and their causes (NGSS Lead States, 2013c, p. 11-12).

Engaging in argument from evidence. Students should be able to use and analyze information, then defend ideas and theories using pertinent evidence (NGSS Lead States, 2013c, p. 13-14).

 Obtaining, evaluating, and communicating information. Students will not only obtain and communicate information, but they will also analyze its relevance and usefulness. (NGSS Lead States, 2013c, p. 15).

The Framework (NRC, 2012), the conceptual precursor to the Next Generation Science Standards, is unsurprisingly quoted throughout the NGSS (NGSS Lead States, 2013i), including the justification and importance of combining science and engineering practices with disciplinary core ideas: “students cannot fully understand scientific and engineering ideas without engaging in the practices of inquiry and the discourses by which such ideas are developed and refined. At the same time, they cannot learn or show competence in practices except in the context of specific content” (NRC, 2012, p. 218). Scientific practices, when integrated with science content, are integral in the development of scientific literacy. According to the authors of National Science Education Standards (NSES), scientific literacy is “the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic
and cultural affairs, and economic productivity and includes specific types of abilities” (NRC, 1996, p. 22). The following passage from the NSES further describes the abilities needed in order to be scientifically literate:

Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately. (NRC, 1996, p. 22).

These abilities are developed and described in the standards, and are very similar to the scientific and engineering practices of the NGSS (NGSS Lead States, 2013c). Along with multiliteracies, this study also focuses on science and scientific practices, however, engineering practices as part of the NGSS will not be overlooked if used in the classroom.

**Scientific Practices and Multiliteracies**

Scientific practices and multiliteracies are linked by parallels in the vocabulary and goals. In each, students are challenged to think and communicate in new ways—constructing meaning
from information in a variety of media and circumstances. For example, the following passage describes “Practice 8 Obtaining, Evaluating and Communicating Information”:

Being able to read, interpret, and produce scientific and technical text are fundamental practices of science and engineering, as is the ability to communicate clearly and persuasively. Being a critical consumer of information about science and engineering requires the ability to read or view reports of scientific or technological advances or applications (whether found in the press, the Internet, or in a town meeting) and to recognize the salient ideas, identify sources of error and methodological flaws, distinguish observations from inferences, arguments from explanations, and claims from evidence. Scientists and engineers employ multiple sources to obtain information used to evaluate the merit and validity of claims, methods, and designs. Communicating information, evidence, and ideas can be done in multiple ways: using tables, diagrams, graphs, models, interactive displays, and equations as well as orally, in writing, and through extended discussions. (NGSS Lead States, 2013c, p. 15)

This passage on scientific practices not only speaks to the multimodality of multiliteracies, but also the need for students to be able to both critically consume and produce information.

Participating in scientific practices is integral in the development of scientific literacy, which also exhibits similarities to multiliteracies. For example, in the Executive Summary of the NGSS (NGSS Lead States, 2013h), if the terms “scientific” is removed from the NSES definition of scientific literacy, the remaining description is as follows: “the knowledge and understanding of […] concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity and includes specific types of abilities” (NRC, 1996,
p. 22). In the Executive Summary of the NGSS, the authors describe a goal of “employers [being] able to hire workers with strong science-based skills—not only in specific content areas, but also with skills such as critical thinking and inquiry-based problem solving” (NGSS Lead States, 2013h). Both of these statements speak directly to multiliteracies as related to the creation of independent thinkers capable of participating effectively in the community at large.

Not only do the NGSS (NGSS Lead States, 2013i) and multiliteracies share similar goals, but the method in which scientific practices are implemented in the classroom will likely require the use of multiliteracies. Multimodalities, including the use of visual literacy and gestures, are necessary in the effective use of models and images in science which comprise the bulk of the work in scientific fields. Technology will also play an important role in the scientific practices. For example, file sharing programs and the internet can be instrumental in collecting, organizing, and communicating information. Likewise, programs such as Microsoft Excel allow for easy organization and visualization of numerical data. These are in addition to the technologies associated with the investigations themselves. Multiliteracies and scientific practices, when integrated thoughtfully, can produce a learning environment rich with meaningful experiences.

**Statement of the Problem**

The convergence of multiliteracies and scientific practices is a burgeoning area of interest with an array of research possibilities for a range of disciplinary areas. Utilizing the voice of students in the evolving study of multiliteracies and scientific practices in the elementary classroom will provide a contemporary and valuable perspective on the two subjects, both independently and together in a vastly different social and economic culture than associated with many early studies. Today’s teachers, students, and researchers bring new and varying
experiences and perspectives to the table. Giving young students the opportunity to express their voices in the world associated with science and its practices will provide meaningful insight into the complex process of learning and communicating through multiliteracies from the often overlooked elementary students’ perspective. This study explores the presence of multiliteracies and student voice as they are enacted with respect to science and scientific practices. Although each of these areas has been researched on their own, the three areas have not been addressed together in this fashion. Through attention to student voice and multiliteracies in science, there are expanded opportunities for all students to learn science and reach scientific literacy.

Rationale of the Study

Elementary science education should lay the foundation for future years of science study and possible careers in science fields (NGSS Lead States, 2013i). Rapidly emerging innovations in technology require new skills in communication and thinking in science. Such innovations are encompassed by the broader notion of multiliteracies which continue to evolve. The rationale for investigating the implementation of multiliteracies and its effects on student voice in the context of science and scientific practices is based on the need to understand and provide meaningful and relevant elementary science instruction that enables and challenges students to become scientifically literate in a world that is constantly evolving (NGSS Lead States, 2013h; Collins & Halverson, 2009). In order to maximize science learning and achieve scientific literacy, students must participate in multiliteracy experiences that are meaningful, engaging, and relevant to their lives (NGSS Lead States, 2013h; Collins & Halverson, 2009). So, how, where, and when multiliteracies intersect the NGSS, specifically the scientific practices and student voice in the classroom, warrants further exploration. Current multiliteracies research calls for exploration of the ways in which students are engaged through multiliteracies in all subject areas, as well as a
closer look at what, why, and how students learn (Ajayi, 2011; Collins & Halverson, 2009, 2010; Leu, Kinzer, Coiro, & Cammack, 2004; Merchant, 2009; Moje, 2009). Current research on student voice, particularly in elementary science, is scarce. However, there is a documented need for better understanding of classroom power dynamics associated with voice and their effects on engagement of students with diverse needs, as well as exploring the teacher’s role in addressing such power relations (Angus, 2006; Bolshakova, Johnson, & Czerniak, 2011; Reinsvold & Cochran, 2012). Therefore, this study explores and describes the roles of multiliteracies and student voice within the context of learning science and scientific practices from the perspective of students and teachers.

**Purpose**

The purpose of this study was to investigate the influences of multiliteracies on student voice within the context of teaching and learning science and scientific practices. This influence was present in forms that inhibit and support student voice while learning science and scientific practices. By exploring student voice and multiliteracies, there was an opportunity to observe whether and how interactions among multiliteracies and voice occur and discern their influence on learning science and scientific practices.

**Research Questions**

The overarching question that frames this study is as follows: How are scientific practices, multiliteracies, and student voice enacted in an elementary science classroom? Research sub-questions are as follows:

1. What and how are multiliteracies, science, and scientific practices implemented in the elementary science classroom;
2. With respect to learning science and scientific practices in the classrooms of study, how are student voices engaged through multiliteracies?

3. How do teachers and students perceive multiliteracies, student voice, science, and scientific practices as they are enacted in the classroom?

**Significance of the Study**

There is little to no research pertaining to how multiliteracies, student voice, and the learning of science and scientific practices diverge and/or converge in elementary science classrooms. Ajayi (2010) for example, calls for research to address the following questions: “What are the most effective strategies for teaching multimodal texts in classrooms with ethnic, cultural and linguistic diversity? How can content area teachers extend multiliteracies to their fields?” (p. 411). Moje (2009), in a call for research on multiliteracies, explains that “we need to answer the question of what new and multi-literacies do for children and youth, both in relation to school learning and to other forms of social and cultural development” (p. 358). The results of this study contribute to the findings of how student voice and multiliteracies interact to increase students’ science content knowledge and develop scientific practices leading toward scientific literacy. One dimension of multiliteracies reflects that constantly evolving technologies are becoming prevalent in society. Furthermore, new technologies are commonly used by elementary students in their everyday lives. Therefore, how this and other multiliteracies unfold with the learning of science and its practices within the culture of the classroom provides insights into connections within the larger social milieu. The classroom is no longer an isolated culture for learning and exploring. Student voice in science teaching and learning, with the intent of examining aspects of multiliteracies and scientific practices, provides insights into the
complexities of these factors as teachers and students negotiate them in today’s classroom and beyond.

**Constructivism as a Theoretical Framework**

The constructivist epistemology emerged from cognitive and sociocultural theories of Piaget, Vygotsky, and Howard Gardner, which has evolved over the last fifty years into a keystone perspective for education (Ackerman, 1996; Fosnot, 1996; Glasersfeld, 1996). This study is rooted in a constructivist framework which asserts that “the world is socially constructed” (Kincheloe, 2005, p.2). This framework places students as active constructors of knowledge, rather than passive receivers of knowledge. Constructivism as an epistemology focuses on the origin of knowledge within the individual and the way they make meaning of their world. Also emphasized in the constructivist viewpoint is the importance of peer collaboration and “democratic and non-hierarchical decision-making” with the intent of “promoting classroom discourse in which participants learn to recognize their peers as potential resources” (Schweitzer & Stephenson, 2008, p. 585). Thus, in this study the world is the culture of the classroom and the intent is to explore meaning-making and the social dynamics of the participants surrounding voice, multiliteracies and learning science and its practices.

By framing the study in constructivism, the grounded theory approach will also be constructivist in nature with the researcher positioned “as the participants’ partner in the research process, rather than as an objective analyst of subjects’ experiences” (Mills, Bonner, & Francis, 2006a, p. 12). Constructivism as a research epistemology positions the researcher neither as an objective bystander nor participant, but as a co-constructor of the participants’ narrative (Mills, Bonner, & Francis, 2006a, 2006b). In this study, I use the term “partner” loosely, as I will not be
a participant. However, I was very aware that as I interviewed students individually and in focus groups, there was potential to unintentionally influence their responses through body language, the questions I asked, or simply because I am an adult. I attempted to reduce this influence as much as possible by remaining aware of myself, the students, and our environment through memo-writing and reflexive journaling. Charmaz (2006) describes constructivist grounded theory as the attempt to “study how—and sometimes why—participants construct meanings and actions in specific situations” (p. 130). Data collection methods such as semi-structured interviews, focus groups, and observations allowed for examination of the areas of interest with respect to the individual as well as the larger classroom culture.

Overview of the Research Methods

Using a grounded theory approach, this collective case study utilizes varying forms of data generation and analysis over the course of five months in two elementary classrooms with teachers Ms. Tyson (5th grade) and Ms. Randall (4th grade). In keeping with the constructivist framework which emphasizes that knowledge is socially and actively constructed, student voice was attended to in three varying situations: voices in the classroom as a whole, collaborative voices in small groups, and individual student voices. In-depth interviews were conducted with two teachers, and hour-long observations were conducted up to five times a week. During this time, focus was given to voices in the classroom within the contexts of science practices and multiliteracies: teacher to student, student to teacher, student to student. During observations, special attention was given to classroom teaching and learning that included the presence of scientific practices and multiliteracies in order to document their implementation or lack thereof. Scientific practices, for example, include the development or use of models, making observations or measurements, collecting and interpreting data (NGSS Lead States, 2013c). Evidence of
multiliteracies included the use of multimodal resources, situated social practice, and the utilization of collective intelligence through collaborative assignments (Lankshear & Knobel, 2006).

The second focus, voices in the collaborative setting, was attended to through observations of collaborative work in the science classroom and explored further in student focus groups. The intention of this phase was to better understand and document the social processes that influence student voice in collaborative situations. During the focus groups and observations, I chose four students (two from each class) through purposeful, selective sampling to study further for the third focus—the student voice. Maintaining a constructivist approach to grounded theory, the specific criteria for selecting individual students for this phase was determined during the first stages of data collection as categories arose and warranted further exploration. For example, Kevin, an African-American fifth grader, was selected because of both his quiet nature in class and his insightfulness during a focus group. During this phase, observations continued as the focus was directed toward individual students. Two or three individual interviews were conducted with each student. Interview protocols were developed based upon observations and emerging patterns or categories in the data.

Throughout the research process, interview and focus groups were audio-recorded and video-recorded, then transcribed verbatim, along with observation field notes and researcher memos. Data transcripts were input into Atlas.ti (2011), a qualitative software program, and then coded line-by-line for examples or evidence of scientific practices, multiliteracies, or student voice. Data was continuously read and re-read throughout the research process as categories and themes emerged.
Limitations and Assumptions

Although the qualitative approach to the study generated rich and meaningful data, the small number of participants and single setting is not intended to be generalizable. As Stake (1995) notes, “the real business of case study is particularization, not generalization” (p. 8). Teacher and student willingness to be honest and open during interviews and focus groups is always possible limitation to reliable data. I felt comfortable with my ability to create a reciprocal relationship with the classroom teachers, as I am newly out of the classroom and still very much think like a teacher. However, creating a personal, reciprocal relationship with the students required constant reflection and attention to the power relations which were present. Kvale and Brinkman (2009) reference Eder and Fingerson (2002) when they state that special attention must be given “to the power imbalance between the child and the adult, and the need for the interviewer to avoid being associated with the classroom teacher, as well as to refrain from conveying expectations that there is one right answer to a question” (p. 146). I did not want the students to see me as another teacher, but rather as a conversational partner whom they could trust and share in the process of creating a narrative of their feelings and experiences. In order to achieve this goal, I explained to the teachers that I wanted to refrain from having conversations with them in front of the students, but would instead like to speak with them before/after school if needed. This proved to be difficult as Ms. Tyson, was still inclined to “chat” with me in front of her students.

Two teachers, Ms. Tyson and Ms. Randall, participated in the study. Both consent and assent forms were obtained from the students in their classes following IRB protocols. In order to generate data on the phenomena of study, it was assumed that the teachers would incorporate multiliteracies and scientific practices into their instruction. Access to a school was granted
through meetings with district office personnel and the school principal. Teachers were chosen through principal recommendation based on him being provided an overview of the study and criteria for selection that included the daily science instruction and use of multiliteracies as well as teacher willingness to participate in the study.

**Researcher Positionality**

Having worked in the school district before, I am acquainted with several of the teachers in the school building, as well as several district office employees. Although I do not personally know the two teachers chosen for this study, my closeness to the school district may have caused a biased view of the teachers’ practices in the classroom as I am aware of the district’s mission and overall expectation for classroom teaching. On the other hand, this kind of information gave me unique insights.

As a former elementary teacher and current elementary science methods instructor, I entered this study with the personal belief that encouraging scientific practices and literacy through the use of multiliteracies will grow in importance in the upcoming years, to the point that the two phenomena will not exist without each other. Likewise, I do not believe that proficiency in scientific literacy or multiliteracies can occur without encouraging and valuing student voice in the classroom. My personal teaching style is one that relies heavily on listening to students and forming positive teacher-student relationships. Although I believe my willingness and ability to connect with students was beneficial when conducting focus groups and interviews, I am aware that the students’ relationship with the teacher may not reflect my personal teaching style. With a background in elementary science education and an undeniable interest in the importance of multiliteracies, scientific literacy, and student voice, I remained
aware of my own biases during the research process by using a reflexive journal to record personal thoughts and feelings.

**Definition of Terms**

*Multiliteracies* are the ways in which individuals negotiate meaning and interact with others through changing technologies and distributed systems in a diverse, globalized world. Fundamentally different from traditional hierarchical organizational systems, distributed systems consist of “many small, efficient, and self-controlled local units [which] act in a fluid, flexible and sometimes ephemeral combinations (networks, patterns) so as to adapt to and transform ‘environments’ (contexts) to which they are integrally linked” (Gee, 2000, p. 44). Multiliteracies are an integral component of being successful in such systems. Evidence of multiliteracies practices in a school setting include (but are not limited to) the following:

1. **Technology**: The use of technological tools by the teacher or students to facilitate learning. Examples of hardware and software programs not limited to but may include the use of laptops, desktops, mobile devices, social media, interactive white boards, the internet, Google applications (Drive, Gmail, etc.), Microsoft Office (e.g. Excel, Word, Publisher). These tools can be used to gather, create, and/or communicate information.


3. **Multimodal teaching/learning**: Having or using more than one mode (e.g. text, still images, video, audio, manipulatives, class discussion).
4. **Collaboration**: Working with others to accomplish a common goal.

5. **Valued diversity**: Valuing the local diversity of a classroom can include incorporating students’ cultures and varying language into classroom teaching and learning. This can be accomplished for instance, through topics of study or literature resources.

*Student voice* is communication and/or ideas, knowledge, and feelings of students that are believed to offer a unique perspective and warrant attention. Student voice is not limited to strictly oral communication, as it can be expressed through dialogue, written work, illustrations, or other multimodal means.

*Student empowerment* is the result of students’ engagement in learning with the goal of rectifying issues of inequity and social injustice within social, academic, and political dimensions (Dimick, 2012).

*Constructivism* as an epistemology asserts that learners construct knowledge actively through social processes and experiences. Emphasized in the constructivist epistemology is the notion that learning is active, reflexive, social, and interpretive (Fosnot, 1996).

*Scientific literacy* is a goal of science education and includes “the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity” (NRC, 1996, p. 22).

*Scientific practices* refer to the eight science and engineering practices of the NGSS listed below:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models

3. Planning and carrying out investigations

4. Analyzing and interpreting data

5. Using mathematics and computational thinking

6. Constructing explanations (for science) and designing solutions (for engineering)

7. Engaging in argument from evidence

8. Obtaining, evaluating, and communicating information (NGSS Lead States, 2013c,p.1)

Summary

Due to innovations in technology, the world is becoming globally connected while at the same time more locally diverse (Cope & Kalantzis, 2000, 2009). Therefore, the influence of multiliteracies on student voice in the teaching and learning of science and scientific practices is a process that warrants investigation to gain insights into how to better prepare and encourage students to become informed citizens and have opportunities to enter into science, technology, engineering and math (STEM) fields if they so choose. To meet the challenges of an evolving local and global society, we require a new way of thinking about society, information, and communication. However, in order to maximize the impact of science learning and multiliteracies, student voices must be attended to. Social processes in schools are complex and weave themselves into the fabric of human interactions, affecting teaching and learning in the culture of each classroom. This study explored multiliteracies as they influence student voice and social processes associated with the teaching and learning of science and scientific practices of two elementary classrooms.
In Chapter 1, an overview of the rationale for the study was provided, including the statement of the problem, significance of the problem, purpose of the study, research questions, an overview of research methods, limitations, assumptions, and definition of terms. In Chapter 2, relevant literature will be discussed pertaining to multiliteracies, scientific practices, constructivism, and student voice.
CHAPTER 2—REVIEW OF LITERATURE

Cope and Kalantzis (2000) argue that a fast paced capitalist society requires “adaptation to constant change through thinking and speaking for oneself; critique and empowerment; innovation and creativity; technical systems and thinking; and learning how to learn” (p. 12). From this stance, elementary classrooms must continue to adapt to meet the evolving needs of students in order to make learning relevant and meaningful in today’s global society. The newly released Next Generation Science Standards (NGSS) (NGSS Lead States, 2013i) emphasize the demand for students to not only learn disciplinary content, but to become experienced problem solvers and data analysts. The NGSS also specifically address the use of technology as a way to go about solving problems and analyzing data (NGSS Lead States, 2013e).

Technology, however, is not the only societal change trickling into classrooms. Linguistic and cultural diversity, along with globalization, require a new commitment to individualized instruction while at the same time encouraging collaboration and respect for others. Attention to student voice by encouraging students to become active participants in their own learning not only has implications for meaningful learning, but also for the future of student empowerment and social change.

This chapter begins with a discussion of scientific literacy and the NGSS (NGSS Lead States, 2013i). The scientific practices of the NGSS are defined and described in detail with examples and supplemental research (NGSS Lead States, 2013i). Connections to the Common Core State Standards (CCSS) are also addressed (National Governors Association Center for
Best Practices [NGA Center] & Council of Chief State School Officers [CCSSO], 2010). A discussion of multiliteracies begins with its history as a concept, along with an in-depth exploration of its varying components including new literacies and technology, distributed systems, and collaboration. The integration of multiliteracies in science education is described with an emphasis on technology use, as well as multimodality and visual literacy. Student voice and empowerment are explored as they pertain to educational research, teaching and learning, and multiliteracies. The chapter concludes with a description of constructivism as a theoretical framework, its relevance to this study, and cross-cutting themes in the research on multiliteracies, scientific practices, and student voice.

Scientific Literacy and the Scientific Practices

Scientific Literacy

Scientific literacy as a goal for science education, encompasses a variety of components, that when put together create a way of thinking rather than a specific experience. Even so, there are conflicting views on scientific literacy and the contributing factors that lead to such literacy. Holbrook and Rannikmae (2009) outline several perspectives over the past four decades and conclude that the current view of scientific literacy is also changing:

The trend […] is suggested as away from the short term product approach, in which the facts and skills are paramount, towards the inclusion of issue-based teaching, the need to go beyond scientific problem solving to encompass socio-scientific decision making, and the recognition that scientific literacy relates to enabling citizens to effectively participate in the real world. (p. 279)
Simply put, scientific literacy is more than the attainment of scientific knowledge; the goal is greater, and the process of reaching the goal is more important than ever. The process is part of the goal. For instance, science education must adapt to societal changes including globalization and technologization (Hurd, 1970). Fifteen years ago Hurd (1998), proposed a change in science education. Instead of emphasizing solely science content, he said students should be engaged in a “lived curriculum […] where students have a feeling that they are involved in their own development and recognize that they can use what they learn” (p. 411). In today’s science classrooms where instruction is frequently guided by state and national standards, this type of “lived curriculum” is needed and essential to progressing toward the goal.

In order to be scientifically literate, students must be given the opportunity to think critically and creatively, beginning in the earliest of grades. Although many would like to believe that “thinking outside of the box” is a natural talent, the skills associated with problem solving can be developed and honed through thoughtful teaching and learning experiences.

Unfortunately in the United States, high-stakes testing has seemingly backed teachers into a corner, creating a teaching climate that is not conducive to problem solving and critical thinking (Berliner, 2011). Berliner argues, “American’s economic competitiveness in the twenty-first century, and surely will contribute to intelligent citizenship in our science- and technology-rich future, has been sacrificed for the possibility of scoring a bit higher on a high stakes test” (2011, p. 291).

Compounding high stakes testing is the effect of No Child Left Behind (NCLB) (2002) on science teaching in the United States with its emphasis on predominantly reading and mathematics which has had a documented negative effect on science teaching. A survey of 164 teachers (K-6) was conducted in 2006 to determine the initial impact of NCLB on elementary
science instruction (Griffith & Scharmann, 2008). For instance, of the 164 teachers, 59.1% stated that they have reduced the amount of time for science instruction in their classrooms since the adoption of NCLB (Griffith & Scharmann, 2008, p. 39). Of those teachers, 71.8% decreased their science instruction thirty-one to ninety minutes per week, resulting in 53.6% of the teachers surveyed spending less than ninety minutes per week teaching science (Griffith & Scharmann, 2008, p. 39). When asked, the surveyed teachers noted the emphasis on reading and math (tested subjects) as the major contributing factor when allocating time for science instruction (Griffith & Scharmann, 2008). A more recent study examined this further by exploring teachers’ beliefs about teaching science after the implementation of NCLB compared to before NCLB (Milner, Sondergeld, Demir, Johnson & Czerniak, 2012). Many teachers explained that their science teaching practices are also influenced by local forces (administration and peers) rather than federal mandates (Milner et al., 2012). The top-down pressure rests on the shoulders of classroom teachers, ultimately affecting their perceived ability and/or willingness to teach science.

It is an understatement to say that it is impossible to achieve scientific literacy if students are not taught science. In classrooms where science is taught, the influence of inquiry-based science teaching is recognized by many as an effective method of instruction. The NRC (1996) defines inquiry as the following:

[…] a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. (p. 23)
Many of the research studies concerning inquiry teaching describe the perceptions and beliefs teachers have on a variety of topics, mainly with implications for professional development and teacher education. For example, Ireland, Watters, Brownlee, and Lupton (2012) found that elementary teachers describe their inquiry teaching experiences in terms of student engagement, teacher-generated questions, and student-generated questions. Also, Capps, Crawford, and Constas (2012) conducted a thorough analysis of empirical research studies pertaining to professional development and inquiry, and found that in order to effectively implement inquiry in the classroom teachers need a strong background in science content, pedagogy, and inquiry-based approaches (p. 307). Hopefully, as states across the United States adopt the NGSS, a renewed emphasis on professional development for teachers in science content and inquiry pedagogies will occur.

**The Next Generation Science Standards**

It is clearly stated that the NGSS are a set of “learning goals” and “indicators of NGSS Lead Statement” (NGSS Lead States, 2013i, p.2). The standards are organized by grade level through the fifth grade and then located in grade bands (6th-8th grade) and (7th-12th grade). Underlying each set of grade level performance standards are three dimensions (Science and Engineering practices, Discipline core ideas, and Crosscutting concepts) which work together to increase students’ engagement and understanding. The three dimensions were presented first in the *Framework for K-12 Science Education* (NRC, 2012) as a response to the strands for scientific literacy in the NRC’s *Taking Science to School* (2007). However, the NGSS Lead States (2013i) recognize that the world is drastically different than it was when the last national science standards were written in 1995, and the new standards are broadly stated to address these
social, economic, and scientific changes. The goal of the NGSS is to increase interest in STEM while preparing students for success in college and the workplace (NGSS Lead States, 2013i).

Before describing the scientific practices in detail, it is best to have an understanding of the other two NGSS dimensions: crosscutting concepts and disciplinary core ideas. The disciplinary core ideas, as also described in the Framework, are a “developmental progression…designed to help children continually build on and revise their knowledge and abilities…toward a more scientifically based and coherent view of the natural science and engineering, as well as of the ways in which they are pursued and their results can be used” (NGSS Lead States, 2013b, p. 1; NRC, 2012). The disciplinary core ideas are organized into the following: physical sciences, life sciences, earth and space sciences, and engineering, technology, and applications of science. Within each core idea, specific scientific concepts are addressed such as “Structure and Properties of Matter,” “Weather and Climate,” and “Earth Materials and Systems” (NGSS Lead States, 2013b).

The crosscutting concepts, similar to broad overarching themes across the disciplinary core and scientific and engineering practices, are present to “bridge disciplinary boundaries, uniting core ideas throughout the fields of science and engineering” (NGSS Lead States, 2013d, p. 1). The crosscutting concepts, or unifying themes, are as follows:

1. Patterns
2. Cause and effect
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter

6. Structure and function

7. Stability and change (NGSS Lead States, 2013d, p. 1)

These crosscutting concepts are to be explored and reinforced through the core ideas and scientific practices beginning with kindergarten and continuing through high school. By encouraging students to recognize the crosscutting concepts as they experience science and engineering practices and gain knowledge of core ideas each year, they will have a better understanding of the interconnections spanning science and engineering by graduation.

**Scientific and engineering practices.** The *Framework* and NGSS emphasize the importance of integrating science concepts with practices, stating that the two cannot be mutually exclusive (NGSS Lead States, 2013c; NRC, 2012). Future assessments will reflect this viewpoint, as “they will be assessed together, showing students not only ‘know’ science concepts; but also, students can use their understanding to investigate the natural world through the practices of science inquiry, or solve meaningful problems through the practices of engineering design” (NGSS Lead States, 2013c, p. 1). In the following section, each practice is defined and an example performance standard is listed (for grades 3-5). Relevant research is also provided when applicable.

**Practice 1: Asking Questions (for science) and defining problems (for engineering).**

The *Framework* suggests that “students at any grade level should be able to ask questions of each other about the texts they read, the features of the phenomena they observe, and the conclusions they draw from their models or scientific investigations” (NGSS Lead States, 2013c, p. 4; NRC, 2012, p. 56).
Example: “Ask questions about what would happen if a variable is changed” (NGSS Lead States, 2013c, p. 4).

Engineering practices begin with defining a problem that is to be solved. In many circumstances, student questions can come as a result of interactions with data, reading, previous investigations, or in classroom discussions. However, teachers play a critical role in encouraging and facilitating students’ questions in the classroom.

In a comparative case study, Harris, Phillips, and Penuel (2012) examined teachers’ instructional methods used to elicit and expand upon students’ questions in fifth grade classrooms. Two frequent strategies emerged. The first consisted of asking and inviting “procedural questions that addressed basic, yet important, information on how to accomplish teacher-structured tasks and how to carry out student-generated investigations” (Harris et al., 2012, p. 777-778). The second strategy utilized open-ended questions as a way to “invite wonderment thinking and questions that dealt with hypothesizing and predicting, explaining and clarifying, and making sense of investigative experiences and results” (Harris et al., 2012, p. 778). Although the three teachers in the study were all attentive to students’ questions and ideas, the level in which the questions were developed, refined, and explored varied amongst the classrooms. Because of this, the authors suggest professional development not only on the act of eliciting student question and ideas, but also with the development and carrying-out of said questions (Harris et al., 2012). Children are naturally curious and frequently ask questions about the world around them. With proper professional development and planning, teachers can guide students to refine their questions, ask better questions, and more accurately define problems (Bybee, 2011).
**Developing and using models.** In science, models are used to explain or describe phenomena that are otherwise difficult to explain or unobservable all together (Starr & Krajcik, 2013).

Example “Develop and/or use models to describe and/or predict phenomena” (NGSS Lead States, 2013c, p. 6).

Models can “represent a system under study, to aid in the development of questions and explanations, to generate data that can be used to make predictions, and communicate ideas to others” (NGSS Lead States, 2013c, p. 6). Students will progress from simplistic models in the early grades to more complex/abstract representations in the later grades (NGSS Lead States, 2013c)—“from pictorial representations in the elementary grades to more sophisticated simulations and modeling tools such as spreadsheets and equations in the later grades” (Starr & Krajcik, 2013, p. 32).

**Planning and carrying out investigations.** Students should be able to participate in investigations that span the inquiry continuum—from directed to full as developmentally appropriate.

Example: “Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials is considered” (NGSS Lead States, 2013c, p. 7).

Ideally, a teacher wishing to implement inquiry-based investigations into her classroom would begin at the level in which her students are able to function, then scaffold and fade instruction until students are equipped enough to participate in full inquiry (Gabel, 2006, p. 234). Gabel (2006) suggests utilizing directed inquiry as a means to prepare students for more complex
tasks, particularly when beginning new concepts, then moving from one level to the next as they master each lesson. As students progress, they are expected to use more advanced “reasoning and scientific ideas, principles, and theories to show why data can be considered evidence” (NGSS Lead States, 2013c, p. 7).

**Analyzing and interpreting data.** Students should be able to organize data from investigations in a way that “can reveal any patterns and relationships and that allows results to be communicated to others” (NGSS Lead States, 2013c, p. 9).

Example: “Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings” (NGSS Lead States, 2013c, p. 9).

The NGSS expect that students are able to use a variety of tools in order to accomplish this task, including online and computer software technologies. Programs such as Microsoft Excel allow students to not only perform statistical evaluations of data, but they can also create graphical representations as well.

**Using mathematics and computational thinking.** In the elementary grades, mathematical and computational thinking is best described in the use of quantitative measurements, organizing numerical data, and graphing (NGSS Lead States, 2013c, p. 10).

Example: “Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific and engineering questions and problems” (NGSS Lead States, 2012 F, p. 10).

This practice overlaps almost entirely with the previous two practices (conducting investigations and analyzing data), as it should. One of the guiding principles of the practices is
that they “are not separate; they intentionally overlap and interconnect” (NGSS Lead States, 2013c, p. 3). As part of this practice, students will learn appropriate units of measurement and the appropriate tool to carry out quantitative measurements (Bybee, 2011). Students can also benefit from computer technology in the enactment of this practice as measurements can be recorded and converted into graphical images on computers or mobile devices.

**Constructing explanations (for science) and designing solutions (for engineering).** One of the overarching goals of science education is for students to be able to use evidence to explain phenomena and their causes (NGSS Lead States, 2013c; Bybee, 2011).

Example: “Construct an explanation of observed relationships (e.g., the distribution of plants in the back yard)” (NGSS Lead States, 2013 F, p. 11).

Through the integration of the other scientific practices along with teacher guidance and questioning, students can create theories and explanations to further enrich their understanding of core concepts. This act of explaining and evaluating is a key factor in the process of conceptual change (NGSS Lead States, 2013c).

**Engaging in argument from evidence.** With explanation comes argument. In science, for example, argument based on evidence is a vital process through which the best explanation for phenomena is finally attained (NGSS Lead States, 2013c).

Example: “Distinguish among facts, reasoned judgment based on research findings, and speculation in explanation” (NGSS Lead States, 2013c, p. 13).

Utilizing evidence and analyses attained through the other scientific practices, students can communicate and defend their ideas and theories with confidence. Similar to the other
practices, this practice must be scaffolded and developed. Younger students, for example, can evaluate two explanations for an observation and determine which is better supported by evidence (Bybee, 2011). Upper elementary students, however, can be expected to obtain evidence from relevant resources to support a particular viewpoint, which can then be communicated with others.

From a review of 54 articles, Cavagnetto (2010, 2011) describes three applications of argument-based instruction: socioscientific, structural, and immersive. Socioscientific arguments link science with social issues, both local and global. Structural strategies tend to the organizational and presentation components of argument—in short, teaching students how to argue effectively. Immersive argument strategies specialize in the use of evidence acquired through scientific or engineering practices, with the goal of increasing understanding of the concept being learned. The three uses of argument-based instruction can be implemented in all grade levels. Cavagnetto (2011) also claims that argument can be used as a motivational and engaging tool in learning science. However, in order to be truly effective, the classroom climate must be one that values varying opinions and ideas (Reiser, Berland, & Kenyon, 2012).

The ability to respectfully participate in constructive arguments needs to be cultivated in classrooms. As students are encouraged to find their voice in science through argument, respecting the diverse voices of the classroom will be paramount. Martin and Hand (2007) conducted a case study in a fifth grade classroom to analyze the process of implementing argument into a science classroom. The authors summarize their findings into three major claims: “there is a critical role for the teacher in promoting argument; shifting the questioning pattern produces more active student voice; and as student voice increases, elements of science
argumentation are practiced” (Martin & Hand, 2009, p. 35). These claims reiterate the importance of creating a classroom climate where student voice is elicited and encouraged.

**Obtaining, evaluating, and communicating information.** The ability to “read, interpret, and produce scientific and technical text are fundamental practices of science and engineering, as is the ability to communicate clearly and persuasively” (NGSS Lead States, 2013c, p. 15).

Example: “Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem” (NGSS Lead States, 2013c, p. 15).

The method in which students communicate can vary from informal classroom discussion to formal presentations with visual aids. Through the use of internet technologies, students can not only communicate with their teacher and classroom peers, but with a much wider audience. For example, blogs and wikis provide the platform for widespread information sharing. With the Internet, however, the evaluation of information becomes a particularly important skill to practice. The Internet acts almost as a double-edged sword. On one hand, it allows anyone to share information with the world. On the other hand, it allows anyone to share information with the world. Gee (2013) argues that digital and social media can enlighten and unshackle the disenfranchised, but it can also “make us stupid…and can lead to duping and manipulating people” (p. 6). Just as students are taught how to edit work for grammatical errors, they must be taught how to evaluate online sources for credibility.

**The Common Core and Science.** Science as a discipline is quantitative, descriptive, and heavily reliant on language. Because of this, the NGSS writing team worked with the Common Core State Standards for Mathematics (CCSSM) team, as well as the Common Core State Standards (CCSS) for literacy during the writing process (National Governors Association
Center for Best Practices [NGA Center] & Council of Chief State School Officers [CCSSO], 2010; NGSS Lead States, 2013f). Key connections and alignments were deliberately noted in order to offer coherence across the documents for classroom teachers (NGSS Lead States, 2013f, g). Below is a triple Venn diagram (Figure 1) from the NGSS displaying the relationship between the three learning frameworks.

**Figure 1. CCSS, CCSSM, and NGSS Connections**

![Venn Diagram](image)

*Figure 1. Relationships and convergences found in the Common Core State Standards for Mathematics (practices), Common Core State Standards for English Language Arts and Literacy (student portraits), and the NRC Framework (science & engineering practices). (NGSS Lead States, 2013a, p. 21).*
For example, the CCSS and NGSS both emphasize the need for students to be able to engage in evidence-based argument (NGA Center & CCSSO, 2010; NGSS Lead States, 2013i). “Taking an inquiry approach toward informational texts can allow students to learn how to question and be critical of texts rather than to always defer to the text or use texts simply for finding answers” (Palinscar, 2013, p. 14). By combining the goals of the two sets of standards, students can take part in meaningful, real-world learning. This may enhance opportunities for elementary classroom teachers to teach science in ways that alleviate the pressure of standardized testing whereby students learn and practice literacy and math skills, while participating in science investigations. Instead of science being limited to 20 minutes every other day, science investigations can occur daily and then extend into the traditional reading and math blocks as needed.

The CCSS and NGSS both address the needs of students in a world where technology, globalization, diversity, and social change are identified as catalysts for change in education (NGA Center & CCSSO, 2010; NGSS Lead States, 2013i). Therefore, the following section discusses multiliteracies associated with a new digital age and generation of students as they intersect teaching and learning within current classrooms.

**Multiliteracies**

In 1994, a group of ten educators from a variety of different nations and backgrounds met in New London to discuss literacy in regards to changes in students’ lives, technology, the workplace, language, and the globalization of society (Cope & Kalantzis, 2000; New London Group, 1996, 2000). Realizing that a changing world (particularly changes in communication) requires a change in the way we think about literacy in both teaching and learning, the New
London Group constructed the term “multiliteracies” as a way to describe the “multiplicity of communications channels and media [and] the increasing salience of cultural and linguistic diversity” (Cope & Kalantzis, 2000, p. 5). The New London Group met annually for the next eleven years at the International Conference on Learning, while continuing to work together and independently to further explore the roles and dimensions of multiliteracies (Cope & Kalantzis, 2009, p. 2). The original members of the New London Group (Courtney B. Cazden, Bill Cope, Norman Fairclough, James Paul Gee, Mary Kalantzis, Gunther Kress, Carmen Luke, Sarach Michaels, and Martin Nakata [Joseph Lo Bianco contributed later]) not only pioneered research in the field, but also inspired other current scholars as well (Cope & Kalantzis, 2000).

The idea of literacies as “multiple” derives from the view that “there are many forms of literacy that vary across time and communities—that literacy is a social practice, rather than a set of reading and writing skills to be acquired” (Cervetti et al., 2006, p. 379). More specifically, the New London Group (2000) describes literacies as multiple in two distinct ways. The first idea being that current societies are literally linguistically diverse and exist within a swirl of mingling cultures (New London Group, 2000). Increasing diversity, due to any number of factors, requires a new focus on students’ unique cultural capital as well as a need for more individualized instruction. The second mention of literacy as multiple refers to the increasing ways in which text and communications are now represented due to technological advances. Combined, these “cultural differences and rapidly shifting communications media meant that the very nature of the subject—literacy pedagogy—was changing radically” (New London Group, 1996, p. 63). The ways in which students interact with text, languages, and each other is changing, necessitating a literacy pedagogy reform.
Out of the two “multiple” foci of multiliteracies arose two pedagogical arguments. The first addressed the multimodality of meaning-making, “where the text is also related to the visual, the audio, the spatial, the behavioral, and so on” (New London Group, 1996, p. 64). The group recognized that technology innovations were occurring at an astronomical rate and showed no signs of slowing. This constant technological change implies that “there cannot be one set of standards or skills that constitute the ends of literacy learning, however taught” (New London Group, 1996, p. 64). This quote begs the question, if there is not one set of skills, then how can one test assess all students?

The second focus is directed to social implications and multiliteracies pedagogy. “Effective citizenship and productive work now require that we interact effectively using multiple languages, multiple Englishes, and communication patterns that more frequently cross cultural, community, and national boundaries” (New London Group, 2000, p. 6). Multiliteracies pedagogy seeks to empower students to embrace this diversity in the process of instigating social change (New London Group, 2000). In order to meet the needs of all students, four pedagogical practices are introduced: Situated Practice, Overt Instruction, Critical Framing, and Transformed Practice (Cazden, 2000; New London Group, 2000).

Situated Practice and Overt Instruction have been compared to the well-known teaching practices of phonics and whole-language (Cazden, 2000). However, in modern classrooms the relationship between the learner and their surroundings, including other students, the teacher, and the text, is quite complex. Situated Practice is an “immersion in meaningful practices within a community of learners who are capable of playing multiple and different roles based on their backgrounds and experiences” (New London Group, 2000, p. 33). Overt Instruction is more teacher-directed (though not to be confused with direct transmission approaches) and allows for
explicit instruction when needed to guide students and scaffold learning (New London Group, 1996, 2000). Both Situated Practice and Overt Instruction are developmental and encourage students to be reflexive and thoughtful learners (New London Group, 1996, 2000).

Through Critical Framing, the students are required to step outside of their learning, to see content and language from “historical, social, cultural, political, ideological, and value-centered” perspectives (New London Group, 2000, p. 34). Cazden (2000) suggests that “students of all ages” should be encouraged to take part in this critical examination of representation (p. 263). This becomes increasingly important with the use of computer software or internet content as origin of production can be vague or frequently anonymous (Cazden, 2000). Critical Framing situates the learner as a skeptic of sorts, positioning and repositioning him or her into different contexts in order to make learning more meaningful and personalized.

Transformed Practice is the implementation of learned skills and ideas in new areas, typically framed within students’ personal (or shared) goals and values. At this point, students should be able to apply, transform, reframe, and implement their learning in a “situated, contextualized assessment” (New London Group, 1996, p. 22).

Although the four pedagogical practices span a wide range of implementation possibilities and variations, the importance of learning to “negotiate across differences” by learning the language associated with such negotiations remains an integral role of multiliteracies pedagogy (Cazden, 2000, p. 263). Through multiliteracies, students will be equipped with the language and skills to participate in diverse societies and globalized networks simultaneously while taking an active role in their learning and ultimately social change and progress.
Distributed Systems

The current educational system was created in response to the industrial revolution and has more or less remained stagnant from an organization standpoint since that time. However, today we are in the midst of an “information technology revolution [which] presses a very real, active system to reconsider its fundamental practices” (Collins & Halverson, 2009, p. 18). Being able to participate in this type of fast capitalist society requires ingenuity, flexibility, and ability to collaborate successfully with others (Gee, 2000). In a distributed system, “small, efficient, and self-controlled local units act in fluid, flexible, and sometimes ephemeral combinations (networks, patterns) to adapt to and transform ‘environments’ (contexts) to which they are integrally linked” (Gee, 2000, p. 44). Given the sociocultural surroundings, in education this translates into asking whether a student can adapt their past experiences, skills, and knowledge to participate in meaningful ways? Can the student adapt to new circumstances? New technologies have the capability to play a major role in students’ preparations to participate in current and future workplaces. Implications for educational settings in today’s current climate are grand in scope, as students now need to be prepared to add expertise and value to a setting in which the whole relies on the parts.

Technology and New Literacies

Although not part of the New London Group, Knobel and Lankshear (2006) reference James Paul Gee as an invaluable source of knowledge on “powerful literacy,” an idea that shapes much of their work (p. 17). By 2006, Lankshear and Knobel described the “dramatic emergence of literacy” in terms of the following key developments.
(1) ‘literacy’ replaced ‘reading’ and ‘writing’ in education language; (2) literacy became a considerable industry; (3) literacy assumed a loftier status in the eyes of educationists; (4) ‘literacy’ came to apply to an ever increasing variety of practices; and (5) literacy is now being defined as ‘new.’ (Lankshear & Knobel, 2006, p. 12).

Thus, the term “new literacies” was developed. Although new literacies are an important component of multiliteracies, the terms are not interchangeable. New literacies are reliant upon the use of technology, whereas multiliteracies are much broader in scope. The newness of new literacies, refers to two kinds of “stuff” which Knobel and Lankshear (2006) describe as “technical stuff” and “ethos stuff” (p. 80). Technical stuff consists of digital tools and the skills needed to function with such tools, whereas the ethos stuff is comprised of two mindsets used to “[inform] a literacy practice” (Knobel & Lankshear, 2006).

According to Knobel and Lankshear (2006), the first mindset believes that the world is the same and literacy practices are the same, just with the added use of technology (p. 80). For example, one who subscribes to this mindset may believe that reading a news article online is the same as reading an article in the newspaper, and therefore the same approach to literacy can be maintained throughout such technological changes. The second mindset, to which Knobel and Lankshear (2006) adhere and form their approach to new literacies, is that the world is quite different and new approaches to literacy are needed. It is important to distinguish “new” from “digital” at this point, as simply using a digital tool or piece of technology does not necessarily mean that the use of the technology is new. Because of the frequent misconception that new literacies and technology use are one and the same, “new literacies are better understood in terms of an historical trend rather than in terms of technical specifics” (Knobel & Lankshear, 2006, p. 81).
Collins and Halverson (2009) trace the history of schooling in terms of technological developments and schooling trends beginning with the invention of the printing press to current day homeschooling and learning center movements. It is argued that education in the United States is fashioned around a “factory model” which has remained relatively untouched even through the development of new technologies such as the textbook, radio, and television (Collins & Halverson, 2009). The school “system” has settled into such a grounded equilibrium that even the change in students’ cultural and societal needs have not shaken the system’s foundation. New technologies, however, have changed “the ways we produce, consume, communicate, and think” (Collins & Halverson, 2009, p. 5). They have, in fact, created new environments for which to live and work.

In order to be successful in these types of environment, an individual must move beyond disciplinary knowledge, and “[develop] the ability to work in non-routinized ways on ever more demanding problems in whatever domain they are confronted with” (Gee, 2000, p. 48). Critical thinking, adaptability, problem-solving, and collaboration are essential qualities of a “portfolio person,” who is able to adapt with such skills which should be nonnegotiable, deliberate components of education (Gee, 2000, p. 43). If a student can think and learn, and be self-aware of their ideas and thinking, then skills and disciplinary knowledge will come. However, many traditional ways of teaching are not conducive to building a “portfolio person,” so methods of knowledge building (Scardamalia & Bereiter, 2006) must be researched and adopted as we move forward in this modern era. Scardamalia and Bereiter (2006) define knowledge building as “an attempt to refashion education in a fundamental way, so that it becomes a coherent effort to initiate students into a knowledge creating culture” (p. 2). Traditionally, learning has been identified almost exclusively with schooling—a historically validated viewpoint (Collins &
Halverson, 2009). New technologies provide learning alternatives that may not be synonymous with traditional mass schooling methods or outcomes.

A key difference in the traditional transmission approach to teaching and the knowledge building approach is the idea of “knowledge about vs. knowledge of” (Scardamalia & Bereiter, 2006). Knowledge about can be identified through basic, declarative knowledge, whereas knowledge of is the result of a deeper more conceptual understanding. With the industrial model of corporations, knowledge about was sufficient—each person was only required to be an expert on one discipline or task. With multiliteracies and new distributive organization, knowledge of is more valuable. An integral piece of “knowledge building discourse” is the constant need for “idea improvement” (Scardamalia & Bereiter, 2006). Students should be required to challenge and question current ideas, contribute to existing bodies of knowledge, and understand that learning is ongoing (Scardamalia & Bereiter, 2006). This type of “intentional learning” has long-been advocated in science education (Bereiter & Scardamalia, 1989). However, the current use of multiple-choice, standardized testing instruments align with the knowledge about perspective, not with intentional learning. Here, a distinct disconnect in educational goals and educational practice is observable. With multiliteracies, students must be encouraged to create personal learning goals, and then collaborate with others in order to be successful, even in early childhood classes.

In knowledge building, technology reduces the need for rote or menial tasks as the internet and other computer software programs already possess a wealth of human “knowledge.” Instead of memorizing information, it is more important to know what tool or system to use in order to quickly and reliably locate the needed information. This skill is known as “just-in-time” learning, where “whenever you need to learn something in order to accomplish a task, you can
find out what you need to know” (Collins & Halverson, 2009, p. 14). Supporters of this type of learning argue that instead of trying to teach students everything they may ever need to know in their lifetime (“everything-at-once learning”), students should instead be taught how to use the resources at hand to learn pertinent information as real-world situations arise (Collins & Halverson, 2009, p. 15). The ultimate purpose, then, “is to develop the skills that allow learners to find the right information anywhere, not just in classrooms with teachers” (Collins & Halverson, 2009, p. 15).

**Collaboration in Multiliteracies**

The ability to collaborate with peers is a crucial characteristic of the ‘portfolio person,’ as it is now almost always a requirement for employability. O’Leary, Mortensen, and Woolley (2011) “estimate that 65 to 95 percent of “knowledge” workers across a wide range of industries and occupations in the United States and Europe are members of more than one project team at a time” (p. 461). Therefore, collaboration in the workplace extends beyond working with one team on one project to working with several teams on several projects. The ability to transition in and out of projects effectively is now a required skill (Smith, Mikulecky, Kibby, Dreher, & Dole, 2000). In the educational realm, collaboration and cooperative learning, even at an early age, prepare students for the distributed systems of the fast paced capitalist workplace. Cooperative learning encourages interpersonal skills, individual accountability, and flexibility. Smith et al. (2000) explains that “increasingly workers will need to engage in problem solving, and doing so will create complex literacy demands requiring the flexible use of strategies to carry our diverse tasks” (p. 381). In the classroom, then, teachers must prepare students for the flexibility and cooperative demands of their future careers and workplaces.
Multiliteracies in Science Education

Several commonalities arise in literature on both scientific practices and multiliteracies discussed previously. These include communication, collaboration, independent thinking, and varying uses of technology. For example, whether created by the teacher as an instructional tool or created by students, the use of models in science as a way to visualize the unobservable is consistent with multiliteracies research, specifically multimodal approaches and visual literacy. The mode in which students create or observe models in science is also an area in which multiliteracies can be utilized. Online simulations allow students to visualize natural phenomena and objects in an environment that can be controlled and manipulated (Collins & Halverson, 2009). In fact, technology applications are noted in all of the scientific practices (NGSS Lead States, 2013c). The Framework and NGSS, like multiliteracies researchers, recognize the impact of technology on society, science, and engineering (NGSS Lead States, 2013e; NRC, 2012). The following sections outline literature related to practices of multiliteracies, specifically in science teaching and learning.

Multimodality and Visual Literacy. Science classes inherently lend themselves to the use of multimodal mechanisms, particularly as the emphasis of science curricula is changing from isolated facts and information to focus on key disciplinary core concepts and scientific/engineering practices as well as interconnections and unifying themes (NRC, 2012; NGSS Lead States, 2013i). Multimodality comes into play in a variety ways: tools for instruction and student interaction and the creation of artifacts. For example, when preparing for a science lesson, a teacher relies on a number of tools and resources emphasizing multimodality. For students, many hands-on, inquiry-based lessons are multimodal by nature, as they typically interact with a variety of materials. In a practitioner piece by Goldston, Allison, Fowler, and
Glaze (2013), for example, students explored the rock cycle through a variety of activities including making models with crayon shavings, watching online videos, creating rock cycle comic strips, completing an online web-quest, and classifying actual rocks.

Incorporating the use of new technologies can assist in the planning science and utilizing multimodal instruction. For example, a classroom teacher found that an interactive white board (IWB) was useful when facilitating multiple means of communication in one lesson (or subsequent lessons) on evaporation, allowing for scaffolding in student learning (Gillen, Littleton, Twiner, Staarman & Mercer, 2007). However, it is imperative when preparing teachers to use multimodal instruction in their classrooms that the focus remains on student learning, rather than the novelty of “trying something new.” Anatopoulou, Sharples, and Baber (2011) assert that “through multimodal interactions, learners have the potential to engage with sensory and communicative modalities that are related to the subject matter to be learnt” (p. 267). The emphasis remains on the students, not the tools of instruction.

Although it is easy to focus on technology as the primary source for multimodal instruction, it is not limited to such tools. Visual literacy, for example, “refers to the ability to make meaning from information in the form of the image” (Rowsell, McLean, & Hamilton, 2012, p. 444). Currently, images are becoming increasingly prevalent in everyday communication, as demonstrated in the use of photos and illustrations in websites, blogs, wikis, memes, etc. (Kress, 2003; Lankshear & Knobel, 2006). However, visual literacy can also be addressed through the use of picture books or other traditional texts with images, charts, or diagrams, and even models. In science, this is particularly useful to represent content that can otherwise not be seen (Coleman, Bradley & Donovan, 2012; Coleman & Goldston, 2012). For
example, a diagram or model of the human respiratory system gives students the opportunity to visualize a system they would otherwise be unable to see.

A study by Cohen and Johnson (2012) investigated the effects of images on science vocabulary retention with 89 fifth grade students. Four instructional methods were implemented and analyzed: “Picture Presentation”—word shown with a picture; “Image Creation—No Picture”—students created an image of a word without being shown a picture; “Image Creation—Picture”—students drew an image of a word after being presented with a picture; and “Word Only”—only verbal representations were used (Cohen & Johnson, 2012). In each of the four random student groups, the word was first presented on an index card, pronounced for the students, used in a sentence, defined, and then shown on the index card again. After this standardized approach, one of the four instructional methods was implemented. Retention of the vocabulary words was assessed through a vocabulary comprehension test (fill in the blank and matching) the day after the activity and again two weeks later. In both the next-day and delayed assessments, there was a significant difference in scores between groups with scores increasing as the level of processing increased. This led to the implication that “imagery-based strategies influence vocabulary learning in the science content domain” (Cohen & Johnson, 2012, p. 948).

The arts are also considered multimodal, and have a place in science and other disciplines in education. In a practitioner piece, Smolinski (2011) describes the use of music in his science classroom, primarily as a study tool used to help students prepare for tests. In his experience, students reported that using custom-made songs helped in remembering difficult science terminology (Smolinski, 2011, p. 44).
Being able to utilize and create multimodal artifacts will be imperative in achieving the goal of scientific literacy for all students, particularly with the purpose of encouraging students to be effective communicators (creators and receptors). Online, information can travel globally in seconds. Students must be able to analyze data and information represented in a number of ways (graphs, data tables, text), form inferences from such data, and then communicate their results. Multimodality opens the door for preparing students for a more realistic approach to the communication they will take part in as adults, while reinforcing science concepts. For instance, “providing learners with a multimodal, digitally enhanced environment supports their transition between the real and the symbolic world” (Anastopoulou, Sharples, & Baber, 2011, p. 282), representing the way that many adults interact with technology on a daily basis. As students grow more comfortable with multimodal approaches then analyzing, utilizing, and creating digital work, they have a better chance of reaching scientific literacy in today’s world.

Greer and Sweeney (2012) employed a variety of data collection methods to analyze the ways in which students believe they learn best. For example, one method required that students “draw a picture of themselves with the various things that helped them learn and to comment on how they used them” (Greer & Sweeney, 2012, p. 296). Drawings of 347 students were analyzed, and 67 different items were identified as tools to aid in learning. The top ten most popular items were as follows (beginning with the most frequently mentioned): computers/laptop, interactive whiteboard, dictionary, books, teacher, parents/family, friends, library, calculator, and pencils. The variety of items suggests that students learn in different ways and value tools differently. When asked in questionnaires and interviews about instructional tools, students suggested “that technologies can make concepts easier to understand, more enjoyable, more professional looking as well as providing an incredible resource by way of the
internet” (Greer & Sweeney, 2012, p. 299). Although students seemed to value technology, there 
was no mistaking that they also believed the teacher was an integral part of their education. The 
authors suggest investing in quality professional development where teachers can learn to 
integrate technology into inquiry-based or problem-based learning (Greer & Sweeney, 2012). 
Not only would this enhance teachers’ confidence in implementing technology in the classroom, 
but it would also improve student learning and achievement. Thus, multiliteracies have the 
capacity to enhance students’ classroom experiences through increased engagement, 
individualization, and communication opportunities.

**Student Voice**

There is a moral responsibility for leaders and teachers to invoke student voice—to insist 
upon, enquire to, try to understand, interrogate, and generate student voice as best they 
can. The important thing is the attitude and belief that students have voices and opinions 
and wisdom that is to be respected. (Angus, 2006, p. 378-379)

Although broad in scope, Cook-Sather (2006) defines student voice as the result of a belief that 
“young people have unique perspectives on learning, teaching, and schooling; that their insights 
warrant not only the attention but also the responses of adults; and that they should be afforded 
opportunities to actively shape their education” (p. 360). There is a research base from studies 
done in the 1990s whereby student voice emerged as an area of interest in educational research 
(Lincoln, 1995; Oldfather, 1995; Wade, 1995), though there is little current research from the last 
decade.

Student voice in research is generally presented in two ways: research *about* student 
voice, and research *with* student voice. In many studies, student perceptions are recorded through
interviews in qualitative research and surveys in quantitative studies (cite some of the studies).

The use of student perceptions could, in some instances, be an example of research with student voice. However, the very act of addressing students’ point of view does not a student voice make. Cook-Sather (2006) traces the history of student voice in research from its origin in the 1990s through its development as a concept in educational research. According to Cook-Sather (2006), two words appear frequently in student voice research which are indicative of the overall concept—rights and respect.

Like most elements of student voice, the term “rights” is not easily defined. However, it can be said that student rights “appeal to higher ethical and moral principles such as justice and equity and, ostensibly, suggests a certain inalienable quality” (Cook-Sather, 2006, p. 370). Similarly, “respect” is also a complex term whose meaning does not fit into a neatly packaged box. Cook-Sather (2006) quotes Goldman and Newman (1998) in saying that “respect listens to divergent opinions and looks for the merits they possess” (p. 374). Together, rights and respect lay the foundation for work with student voice, as “rights are more a priori, acontextual, more about givens, attributes of being an individual; respect is socially negotiated, relational, more fully contextual” (Cook-Sather, 2006, p. 376).

In order to respect the rights of students, active and authentic listening must be employed. However, there are certainly challenges that accompany research with or about student voice. One challenge is accepting the notion that student voices are not identical, rather that they change and vary just as adult perspectives vary (Cook-Sather, 2006). We must also be careful not to regard children as some overly romantic or “sweet” sources of information. It is easy to adopt the, “Oh that’s so cute” outlook toward student voice (particularly with very young children), rather than truly valuing their words as merit worthy (Cook-Sather, 2006). Likewise,
while valuing student voice, we must be open to the possibility that what students have to say may not be what we want to hear.

A particular research challenge is valuing the notion that silence is a powerful form of voice, as “silence can mean that a voice is not speaking because it is not worthwhile or safe to speak […]. It can also be an informed choice after attempting to speak and not being heard” (Cook-Sather, 2006, p. 369). Power issues of who can speak and when, who listens and who does not, are present in most student voice research agendas. Researchers must be cognizant of the power of silence in order to best represent the voices of students.

Australia is admittedly a country invested in contributing to student voice research, as well as research using student voice. Smyth (2012) believes that many countries suffer from the “‘adult knows best’ syndrome in which the focus is exclusively on comparative international performance, economic competitiveness and, by and large, a failure to seek or embrace any understandings from young people themselves” (p. 153). Australia seems to be taking part in an over-haul of public education with reforms that value individualization and student responsibility in schooling (Smyth, 2012). Such reforms cannot be successful without input of students on what is happening in their lives both inside and outside of school. Smyth (2012) argues four points that must be in place as you address student voice in education:

- Stand a chance of hearing the issues as they are existentially experienced by young people….

- Develop ways of resolving issues that are likely to impede the learning of young people by integrally involving them from the outset….

- Embrace aspects of young lives that are seen as lying outside of school….
• Confront the burning issue of learning ‘relevance’ as seen from the vantage point of young people. (p. 154)

Accordingly, by addressing these points with the serious intent of listening to students, reform becomes more pertinent to students’ lives and therefore more effective.

**Student Voice in Teaching and Learning**

Furman and Barton (2006) describe two broad types of student voice: student voice as perspective and student voice as participation. Student voice as perspective relates primarily to student beliefs and opinions, particularly pertaining to their school, classroom, and learning. When analyzing student voice as participation, however, Furman and Barton argue that “all students’ observable actions, [including] what students decide not to do” should be recorded (2006, p. 672). Students’ physical, verbal, and even silent actions account for student voice from this perspective (Furman & Barton, 2006).

Lodge (2005, 2008) suggests that students can participate in their own education in four different capacities: quality control, sources of information, compliance and control and surveillance, and dialogue. Quality control includes research methods such as satisfaction surveys and questionnaires that are questioned to gauge student opinions on school matters. As a source of information, students may be asked to describe their interactions with teachers. For compliance and control issues, students are used by outside agents in order to provide information on their schooling. Finally, dialogue is the most open form of participation, where students are engaged in active communication regarding their ideas, interests, and/or opinions. Although students participate in all four of these categories of participation, Lodge (2008) argues that through meaningful dialogue, teachers can engage students to promote meta-learning and
increase the benefits of the students’ overall educational experience. In order to do this, Lodge (2008) suggests four strategies that can be used in classrooms: 1) notice learning, 2) talk about learning, 3) reflect on learning, and 4) learn about learning (p. 9). By engaging in these practices, “every teacher can help young people become better learners within their classrooms” (Lodge, 2008, p. 18).

In the United States, No Child Left Behind (NCLB, 2002) has changed the culture of classroom teaching and learning, especially in elementary schools. Berliner (2011) argues that “some responses to the pressures of high stakes testing are unlawful, and many more are immoral or at least questionable…” (p. 289). Responses to testing pressure have created a narrow curriculum with more emphasis on specific content, specifically reading and math, allowing other subjects and important skills to be ignored (Berliner, 2011). In particular, the arts and sciences have suffered monumentally. Curriculum narrowing leaves little room for student voice and creativity, as rote drilling and memorization become the primary method of instruction. If there is only one answer, then there is no room for individuality or diversity.

Furthermore, curriculum narrowing widens the gap for learning based on the socioeconomic status of students (Berliner, 2011). Affluent students, through family activities such as vacations, trips to museums, and other activities such as these “pick up peripheral, incidental, but potentially essential knowledge, even when their schools do a poor job of teaching about the natural world, art, music, history, geography, and science” (Berliner, 2011, p. 299). Because of this, the negative effects of high stakes testing are exaggerated in students of low socioeconomic status, making the intended efforts of increasing achievement not only negligible but harmful.
Bolshakova, Johnson, and Czerniak (2011) analyzed the self-efficacy of Hispanic middle school students in an urban middle school in an effort to describe the relationship of teacher effectiveness to student success. Bolshakova et al. (2011) emphasized student voice as the most important source of data in their study. Findings suggest that building a relationship with students in which the students feel as though they are heard and valued leads to higher self-efficacy and positive feelings toward science for both the teachers and students (Bolshakova et al., 2011). The authors suggest that teachers should be informed on the impact of such relationships on student learning, and that teachers should be provided with professional development on working with urban students specifically.

Christidou (2011) traces the history of relevant literature pertaining to student perceptions of science and scientists through the voice of students, the voice of teachers, and the voice of popular science. The literature suggests that students’ knowledge of science-related fields relies on a variety of sources including school science and out-of-school science (Christidou, 2011). The author claims that in order to engage students in science curricula, affective as well as cognitive components should be addressed (Christidou, 2011, p. 149). To achieve this goal, science must be taught in a way that peaks interest. According to Christidou (2011), science should be taught as “a) a means to promote practical competence; b) a socio-economic enterprise; c) a vehicle to enhance emotional experience; d) an intellectually challenging endeavor; and e) a vehicle to quality for professional life” (p. 144).

**Power and Student Empowerment**

Power relations remain at the forefront of research in student voice. It appears that research on student voice cannot occur without addressing such power relations, as they affect
nearly every aspect of student voice in schools. Unfortunately, students have “the most important voices that are often not a focus of educational change” (Bolshakova et al., 2011, p. 963). This idea is profound and troubling. After all, student voice as a means to improve teaching and learning must be important. Talk to students, listen to what they have to say, adjust accordingly. Although teachers appear to be open to students’ input, there is still a fear that they may say something we do not want to hear—power relations, again, are at play.

Student empowerment is contingent on the teachers’ self-awareness of beliefs and values (Wade, 1995). Teachers must be aware of their institutional power in order to enable students to take ownership in their learning, as the students are all too aware of their lack of institutional power. Dimick (2012) describes student empowerment in three dimensions: academic, social, and political. Academic empowerment, the most prevalent of the three in classrooms, requires that students are taught the academic knowledge needed to be successful inside and outside of the classroom. Social empowerment involves the development of classroom relationships that are “safe, supportive, nondiscriminatory, and antioppressive” (Dimick, 2012, p. 995). Political empowerment gives students the opportunity to recognize and challenge power inequities in institutional hierarchies. These three facets of student’s empowerment were analyzed by Dimick in a high school environmental classroom in a study on social justice in science education. Upon witnessing the complexity of student empowerment in the classroom, she concluded that “empowerment is not a fixed process, but working toward it as a goal of social justice teaching and learning in science intentionally directs much-needed attention to power relations within science education” (Dimick, 2012, p. 1009).

Robinson and Robinson (2013) conducted a study which analyzed the power relations in school-based projects that were created to promote student voice. The students-as-researchers
(SaR) projects were carried out in two schools (catering to ages 4-11 and 11-16) located “in an area of high social deprivation” in the United Kingdom (Robinson & Robinson, 2013, 36). The goal of the SaR projects was to “enable students to conduct research amongst their peers—sometimes their teachers, parents and governors and the wider school community to produce knowledge based on students’ views and voices” (Robinson & Robinson, 2013, p. 35). One of the authors, Dr. Carol Robinson, was funded by the Local Authority (LA) to work with each school during the development of the projects. After the creation and completion of the projects, the researchers completed interviews with school staff and students in order to gain better insight on their perceptions of the role of student voice and power as well as the success of the projects. From their discussions, it was clear that power was evident in two ways: overt domination and “hidden” domination. In this instance, power as overt domination includes the use of authoritative power by virtue of an institutional role or position of hierarchical authority (Robinson & Robinson, 2013). The use of authority is not always negative, as it can be used to empower others. For example, the head teacher was responsible for introducing the SaR projects to the rest of the school, even though some of the classroom teachers were skeptical or hesitant. Likewise, the LA utilized its financial authority to fund the project. Power as hidden domination is the result of perceived authoritative positions. Examples of hidden domination manifested in informal conversations between teachers and students during the SaR projects, as students were always aware that teachers were in control. The students “only felt able to voice opinions which conformed to the limited remit which they knew in advance would be met with approval” (Robinson & Robinson, 2013, p. 40). Robinson and Robinson (2013) conclude that even though students were not intentionally manipulated, the understated power relations, even in a project intended to empower students, resulted in a final product that “aligned with school institutional
agendas, which help the school to enhance its normative, dominant institutional cultural capital” (p. 43).

A paradigm shift is in order if students are to be expected to be more present in their learning. If teaching is a cultural experience, as noted by Stigler and Hiebert (1999), then teachers and students alike must be made aware of these power issues in the classroom in order to address them—take a step back and look inward. Many teachers will argue that they participate in a particular activity or employ a specific teaching strategy, but upon closer examination it often becomes apparent that they are not quite in touch with their own practices (Stigler & Hiebert, 1999). Addressing and accepting student voice is assuredly no exception. Student voice as a concept is quite broad and elusive. No two voices are the same, which makes defining student voice quite difficult. The complex nature of power relations within student voice research is important to address and virtually impossible to avoid.

**Student Voice in Multiliteracies**

The implementation of multiliteracies in teaching and learning has the potential to alter the current power hierarchies in classrooms through individualized instruction and new communication practices. Currently, many classrooms are structured with the understanding that teachers possess knowledge and expertise that is to be given to students. This notion is mainly problematic when the teacher is seen as the *only* source of expertise and knowledge. Student voice in these situations may be seen as extraneous and not necessary for maximal learning, simply because the voice does not belong to the teacher. This model has been “successful” in the past century because of the “mass-production notion of uniform learning” (Collins & Halverson, 2009, p. 43). Students, as separated by age into grade levels, are expected to learn content
outlined in uniform standards. Through technology, however, information (expert information) is readily accessible to anyone that can connect to the internet, regardless of their geographical location or age (Collins & Halverson, 2009). This open access to information provides vast possibilities for individualization of instruction, but unfortunately other barriers to such learning still exist. The standardized assessments currently in place, for example, do not lend themselves to individualized instruction (Berliner, 2011; Collins & Halverson, 2009). Furthermore, teachers must be educated on ways to integrate technology when teaching standardized curricula. Of course it is fairly easy to utilize technology as a way to reinforce traditional skill and drill practices through a variety of computer games and software programs. It is quite different, however, to encourage in depth, student-led or problem-based projects through the use of countless resources available online or through specialized software programs (Collins & Halverson, 2009).

Not only must the teachers be willing to relinquish a fair amount of power, but school-based technological support and professional development is critical. Individualizing instruction through multiliteracies will enable students to explore interests and avenues during the school day that would otherwise only be pursued outside of school. By recognizing that worlds of knowledge can be held in a computer, we can free a teacher from her duties as a human book and allow her to explore her talents of engaging and inspiring students to seek a deeper more meaningful understanding of content than could ever be imagined. This process has the ability to empower students as they find their own voice in learning, even when taking part in a standardized curriculum (Collins & Halverson, 2009).

The technological aspects of multiliteracies do more than individualize instruction—they expand the cultural and communicative boundaries of classroom walls. Students are now able to
communicate with new people in new ways. For example, technologies such as Dropbox and Google Drive (2015) allow students to share work and ideas instantly with any number of collaborative partners, including other students, professional experts, parents, and teachers, all while documenting each contributor’s actions throughout the process (Denton, 2012). Students can communicate with new audiences daily through blogging and media-casting while interacting with content in new ways through fan fiction and photo-shopping (Knobel & Lankshear, 2006). As this happens, students become active participants in the communication process, not only receiving information, but interacting and creating it as well.

Furman and Barton (2006) conducted a study on the role of student voice in a program where two seventh grade students created a mini-documentary about science using digital equipment. The researchers observed science learning throughout the process, and concluded that the integration of student voice in science through this medium resulted in a positive effect on the students’ science identity as well as their engagement in science. In the urban area in which the study took place, the researchers also observed that using digital tools during science helped to overcome the contradictory feelings of the students—wanting to be knowledgeable about science and technology, and wanting to look cool. Furman and Barton (2006) believe that attending to students’ voices in informal settings will allow for more meaningful uses of voice in more formal classroom settings. Listening to, and appreciating individual voices in the classroom is a valuable tool in creating a classroom climate of mutual respect and willingness to learn.

Multiliteracies literature calls for a new respect and appreciation for varying cultures in elementary classrooms, as local diversity continues to increase. Respect for students’ voices and cultural identities are imperative in this charge. In an ethnographic case study in a 4th grade classroom in Toronto, Giampapa (2010) identified multiliteracies pedagogical practices that
encouraged students to rethink language and identity. For example, the teacher, Perminder, described her classroom as a place where “poetry and art became the textural, multimodal vehicles through which her class tackled critical discussions on identity, language, race, and difference” (Giampapa, 2010, p. 420). With the majority of her class being multilingual, Perminder believed it was her responsibility to “stretch the English mainstream curriculum” in a way that gave value to the students’ languages and cultures (Giampapa, 2010, p. 422). This example illustrates the way in which multiliteracies and student voice scaffold each other in the classroom.

**Constructivism**

Constructivism as an epistemology relies heavily on the notion that knowledge is not a commodity to be transmitted from one person to another, but rather a process of constructing knowledge that derives from previous experiences, social surroundings, and personal beliefs/understandings. The constructivist epistemology emerged from different cognitive, sociocultural, and semiotic interactionist theories of Piaget, Vygotsky, and Howard Gardner (Ackerman, 1996; Fosnot, 1996). By examining the theories of the leaders in the field, Fosnot (1996) may have said it best when he said that learning is an “interpretive, recursive, building process by active learners interacting with the physical and social world” (p. 30). Although this is not a new idea, learning as an active, interpretive, reflexive, and social process is evident in the research on multiliteracies, student voice, and scientific practices. For example, Fosnot (1996) outlines five tenets of constructivist educational practices: “Learning is not the result of development; learning is development,” “disequilibrium facilitates learning,” “reflective abstraction is the driving force of learning,” “dialogue within a community engenders further thinking,” and “learning proceeds toward the development of structures” (p. 29-30). The
constructivist attention to the processes of learning, questioning, thinking, and collaborating is valuable and mirrors the essential features of multiliteracies and the NGSS. Because of this, constructivism is an applicable and relevant framework for this study.

In many classrooms today, learning is segmented by subjects, driven by standards, and broken down into small parcels instead of expanded and made flexible to reveal real-world connections (Scheer, Noweski, & Meinel, 2012). The teaching and learning of multiliteracies and scientific practices, however, rely on the ability of students to engage in experiences that reflect constructionist values. Bentley, Fleury, and Garrison (2007) make it very clear that constructivism is not a teaching method, but rather an epistemology that shapes the attitudes and beliefs that often guide pedagogical practices. Bachtold (2013), suggests that constructivism, as it influences teaching practices, advocates for two strategies: “(1) elicit students’ prior conceptions on the topic being taught, and (2) create a cognitive conflict in students’ minds that confronts their prior conceptions with new phenomena, with the conceptions of other children, or with new knowledge” (p. 2). Assessing prior knowledge and encouraging students to confront ideas and/or misconceptions through hands-on or real-world experiences are two common features of inquiry-based science teaching.

In science classrooms, constructionist teaching values “personal relevance, scientific uncertainty, critical voice, shared control, and student negotiation” (Savasci & Berlin, 2012, p. 66). These tenets were analyzed in a case study of four secondary science classrooms. Although the teachers reported that their classroom teaching reflected their constructivist beliefs, in reality their teaching exemplified a much milder constructivist nature (Savasci & Berlin, 2012). Shared control was “one of the least preferred, least frequently perceived, and least frequently observed components of constructivism” in the classrooms studied. As a result there were frequent whole-
class activities which, according to the teachers, student behavior played a major role in their implementation of constructivist teaching (Savasci & Berlin, 2012).

Within the realm of constructivism, one finds critical constructivism in which the emphasis is on “reflection, imagination, social consciousness, and democratic citizenship” (Bentley et al., 2007, p. 20). Adhering to this way of knowing brings to light the power relations that underpin students’ worlds and experiences, inside and outside of the classroom. Kincheloe (2005) notes that maintaining a critical constructivist view when exploring classroom processes, requires attention to all variables, because these variables “produce a thicker, more detailed, more complex understanding of the social, political, economic, cultural, psychological and pedagogical world” (Kincheloe, 2005, p. 3).

Technology has the capability to enhance constructivist instructional methods. “Cloud computing” through the use of collaborative programs such as Google Drive (2015), student-document sharing, publishing, and collaboration can enable shared control in the classroom as children work not only with their teacher and classroom peers, but with colleagues outside of school walls as well (Denton, 2012). “Cloud computing” refers to technology that enables the sharing of data over the Internet. Collaboration, especially with someone other than the teacher, enables students to share knowledge with each other in order to achieve a goal (Fosnot, 1996). Denton (2012) argues that although “cloud computing as a method for improving academic achievement may seem distant, the way that these tools align with learning theories and modes of instruction suggests otherwise” (p. 40).

This new age of information and communication does not come without challenges. Sharing information requires shared control which, although seen as a challenge to current power
hierarchies, cannot be ignored as a key component of the critical constructivist view. Pascarella (2008) asks the question:

How are teachers prepared to encounter classrooms full of learners with access to an endless supply of communication “vehicles” to navigate new media that empower them with information no longer static and waiting to be read in a dusty textbook published two years ago, took three years to write, and utilized research completed 10 years prior? (p. 248)

The internet and other media-based resources can allow for a broader perspective, as a vast array of information is now at students’ fingertips. “By encouraging students to express feelings related to their work (their frustrations as well as their interests), the teacher can encourage students to consider the entirety of the learning process” (Julyan & Duckworth, 1996, p. 71). This may be difficult in the current educational climate of high-stakes testing, but teachers and students alike are responsible for examining the world around them, and how they are situated in that world (Kincheloe, 2005).

**Summary**

This chapter explored the research base on scientific practices, multiliteracies, and student voice within a constructivist framework. By addressing these concepts first individually and then combined, several overarching themes (and many common subtopics) emerge in the research. As a global society in which information is exchanged at the stroke of a computer key, it is also obvious that many United States classrooms are not keeping pace with the speed at which the world is changing (Collins & Halverson, 2009). A driving force behind the information explosion and the constantly changing face of global society is that of innovations in
technology which are changing. These include: 1) what students need to learn, 2) why they need to learn it, 3) how they can learn it, and 4) how they communicate. It is no longer enough to memorize complex mathematical algorithms or disconnected scientific facts. What is necessary is for students to learn how to efficiently and effectively find or calculate such information (Collins & Halverson, 2009). As such, multiliteracies pedagogy and the NGSS scientific practices are relevant in that they address societal and technological changes (NGSS Lead States, 2013c). The ability to question, solve problems, and utilize and evaluate resources is necessary not only for scientific literacy but for general literacy as well (NGSS Lead States, 2013g). The fast moving capitalist society requires that students learn how to work collaboratively with others to identify and solve complex problems, necessitating effective communication skills (NGSS Lead States, 2013i; Cope & Kalantzis, 2000). In conclusion, multiliteracies and scientific practices are aimed to achieve many of the same goals.

This chapter has addressed the current nature of multiliteracies, science and scientific practices, and student voice in education. Also discussed was constructivism as a theoretical framework, including the underpinning of critical constructivism and constructivism in the digital age. The following chapter will outline the research context and research methods for the study including participants, data collection, and data analysis.
CHAPTER 3—METHODOLOGY

This chapter outlines the theoretical and methodological frameworks that were used to investigate the presence of multiliteracies, student voice, and scientific practices in two elementary classrooms. The evolving nature of multiliteracies coupled with the recent publishing of the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013h) frame this study in a contemporary context. This is further supported by the significance of exploring student voice in elementary classrooms as these new literacies and practices unfold. In this chapter, you will find a discussion of the theoretical framework applied in the study as well as a description of the research context and methods including participants, data collection, and data analysis.

Theoretical Framework

The social and cultural nature of multiliteracies and scientific practices naturally lend themselves to being explored through a constructivist lens. As a way of looking at the origin of knowledge, constructivists claim that “not only is the world socially and historically constructed, but so are people and the knowledge people possess” (Kincheloe, 2005, p. 2). As students participate in new experiences, interacting with the social and natural world, they are constantly negotiating meaning between prior experiences and new cognitive schema (Brooks & Brooks, 1999). Constructivism is not a theory, it is an epistemology of how knowledge originates. Teachers who embrace a constructivist view in the classroom employ practices that encourage meaning-making through contextually rich experiences, rather than traditional transmission teaching approaches (Fosnot, 1996).
In terms of teaching and learning, characteristics of a constructivist classroom parallel many of the overarching concepts of inquiry-based teaching and multiliteracies pedagogy. In each, students are encouraged to participate in solving problems of cultural and social relevance as part of a deliberately meaningful (rather than disjointed) curriculum. Fosnot (1999), for example, describes the constructivist classroom as a place in which students “search for patterns, raise their own questions, and construct their own models, concepts, and strategies” (p. ix). This description directly reflects the scientific and engineering practices of the NGSS which also require students to ask questions, create models, and formulate explanations (NGSS Lead States, 2013c).

Student voice also shares constructivist values and classroom implications. Brooks and Brooks (1999) outline five characteristics of a constructivist classroom, one of which is that “teachers seek and value their students’ points of view” (p. 60). Through thoughtful questioning and engaging problems, teachers “maximize opportunities for students to express their points of view, to reveal their conceptions, to reflect on their conceptions, and to grow intellectually” (p. 65). By questioning and encouraging listening to students’ reasoning and thinking, teachers give importance to the process of learning, creativity, and independent thinking.

Constructivism as a framework for educational research “places priority on the phenomena of study and sees both data and analysis as created from shared experiences and relationships with participants” (Charmaz, 2006, p. 130). Furthermore, this approach is more than just a description of participants’ experiences, but evolves toward an interpreted theory of “learning how, when, and to what extent the studied experience is embedded in larger and, often, hidden positions, networks, situations, and relationships” (Charmaz, 2006, p. 130). Denzin and Lincoln (2000) describe the constructivist paradigm as “a relative ontology (there are multiple
realities), a subjectivist epistemology (knower and respondent co-create understandings), and naturalistic (in a natural world)” (p. 24).

Research Methods

Denzin and Lincoln (2000) assert that “qualitative researchers stress the socially constructed nature of reality, the intimate nature of reality, the intimate relationship between the researcher and what is studied, and the situational constraints that shape inquiry” (p. 10). The research questions that guide this study lend themselves to an in-depth look at classroom cultures, which requires extensive classroom observations as well as in-depth interviews with teachers and students. Marshall and Rossman (2011) describe case studies as a strategy that “focuses on society and culture in a group, a program, or an organization” which requires “immersion in the setting and rests on both the researcher’s and the participants’ worldviews” (p. 93). Worldviews, as defined by Keane (2008), are “deep, ontological/philosophical, representational knowledge; foundational presuppositions about reality” (p. 591). In order to explore teachers’ and students’ perspectives on multiliteracies and scientific practices, along with student voice which is quite personal, a multiple case study approach has been chosen as the overarching research method. Data were collected in two classrooms through observations, teacher interviews, focus groups with small groups of students, and interviews with a select group of individual students. This ultimately creates a multiple or “collective case study” (Baxter & Jack, 2008; Stake, 1995). This method allowed for a deeper insight into the presence and perceptions of multiliteracies, student voice, and scientific practices within and between each classroom.
Research Design

The research questions that drive this study are as follows:

1. What and how are multiliteracies, science, and scientific practices implemented in the elementary science classroom?

2. With respect to learning science and scientific practices in the classrooms of study, how are student voices engaged through multiliteracies?

3. How do teachers and students perceive multiliteracies, student voice, science, and scientific practices as they are enacted in the classroom?

Setting

From this point forward, pseudonyms are used for all people and places in order to protect anonymity of the participants involved. The study took place at Littleton Elementary, a K-5 elementary school in a small city school district, adjacent to a larger urban city in the southeastern United States. Morning City School System is composed of only three elementary schools, one middle school, and one high school. The district’s mission and belief statements, as stated on their website, promote multiliteracies as described in this study, student voice, and scientific practices of interest in this study. These include: a) Developing 21st century learners by fostering problem solving skills and creativity to prepare learners for an integrated global society, b) Developing students’ communication skills for growth and collaboration, c) Fostering opportunities for collaboration to strengthen social skills, d) Inspiring creativity and innovation in learning and teaching, e) Assessing curriculum for critical thinking experiences, f) Motivating student to participate in the community, recognizing ownership in a global society, g)
Providing experiences that contribute to cultural awareness, and h) Promoting environmental consciousness.

To gain access to Morning City Schools, I met with a member of the district office staff and presented an overview of the study goals and timeline. This person not only works as the district’s Director of Instructional Support, but he also teaches education courses at a local teaching college. He was enthusiastic about my study and suggested Littleton Elementary as the study’s setting. Littleton Elementary is a Title I eligible school with 29% of its 610 students receiving free or reduced lunch. The demographic breakdown is as follows: 2% Asian, 21% African-American, 10% Hispanic, and 66% Caucasian. With a total of 65 teachers, Littleton’s motto as stated on their webpage is “Littleton educates, respects, protects, and loves children.”

Participants

The study was bounded in two classrooms (4th and 5th grade). In order to fully address each question, the units of analysis for this study were the two teachers and their students. Although this was his first year as the principal, Mr. Miller was quite familiar with the teachers and their teaching styles. For the past three years, he has worked as the assistant principal of the school offering instructional support for teachers. During the first meeting with Mr. Miller, I presented the selection criteria for participants as well as a general overview of the study, as Stake (1995) explains that the first criterion for choosing a case “should be to maximize what we can learn” (p. 4). The teachers were purposefully and selectively chosen based on the criteria that they teach science daily, utilize technology on a regular basis for teaching and learning, and employ a hands-on or student-centered approach to teaching and learning in order for the sample to better lead to theory development (Charmaz, 2006). In addition, the selection was limited to
upper elementary classrooms (grades 3-5) for two reasons. First, upper elementary teachers tend to implement science on a more regular basis than early childhood classes. Second, older students will be able to better articulate their thoughts in an interview setting, more-so than early childhood students. After meeting with Mr. Miller and sharing the criteria, he listed the teachers he felt were appropriate. He met with the teachers, of which two volunteered to participate—Ms. Randall (4th grade) and Ms. Tyson (5th grade). Ms. Randall’s enthusiasm was evident in an email sent to me where she stated, “I’m looking forward to it as I think it will be great feedback for me and I certainly hope it will be helpful to you!” Ms. Tyson, on the other hand, was eager to meet in person to talk about the details: “I would love to meet with you and hear more about it.” I met with the two teachers (individually) where I again explained the criteria for participating in the study. I also shared general details of the study, including a timeline and data collection methods. After these conversations, the teachers explained that they had a better understanding of the study and looked forward to participating.

Protection of Privacy/Confidentiality

Upon approval from the Institutional Review Board (IRB) (see Appendix A), written permission was granted from the school district and school principal. Informed consent was obtained by the teachers before initial interviews (see Appendix B). In working with students as participants, confidentiality is of the utmost importance. Consent was obtained by the students in the classroom setting. First, I read the Parental Permission form (see Appendix C) aloud to the students and answered questions pertaining to the study. The Parental Permission Forms were sent home and collected by the teacher over the course of two weeks, though most were returned within a day or so. With the assistance of the teacher, I distributed an assent form (see Appendix D), read it aloud, and answered student questions. Because children are particularly vulnerable, it
was made quite clear that withdrawal from the study at any time was permissible. All 20 students of Ms. Tyson’s class returned Parental Permission and Assent Forms, though one chose not to be video-taped. A student enrolled in the last half of the study, and he too returned the Parental Permission form and Assent Form. Four students chose not to be video-taped. Of the 21 students in Ms. Randall’s class, 16 returned Parental Permission forms, of which four chose not to be video-taped. The five students that did not return Parental Permission forms were not included in data collection. As noted earlier, pseudonyms will be used in all stages of the study to insure anonymity of participants. Paper data is stored in a locked file cabinet, whereas digital data is stored in ATLAS.ti (2011) on a password protected computer located in my home. ATLAS.ti (2011) is a qualitative software program used in the study for data analysis.

Preserving the confidentiality of the students during focus groups and individual interviews required careful consideration. The students were informed that their responses would not be shared with their classroom teacher (nor have any impact on their grades), nor would their actual name be associated in any way with their responses. Focus groups and interviews were directed toward classroom observations to protect the personal privacy of the students.

Data Collection Overview

The data collection methods for this study were chosen as a way to address the research questions while allowing room for exploration of emerging data (Charmaz, 2006; Stake, 1995). As Charmaz (2006) explains, grounded theorists “follow leads that we define in the data, or design another way of collecting data to pursue our initial interests” (p. 17).

Interviews and focus groups. Throughout the study, semi-structured interviews were conducted with the teachers and students. An outline of topics, along with preliminary questions,
was created prior to each interview (Kvale & Brinkmann, 2009). The questions were structured in a way that addresses “collective practices” at first, and then moved toward the participant’s individual experiences and perceptions (Charmaz, 2006, p. 29). Conversational interviews were also conducted throughout the study. Although I attempted to reduce my impact on the students during instructional time, the students were eager to engage in conversation. As I became more familiar to the students, I was engaged in informal conversations with them on a regular basis.

Focus groups, which can consist of up to ten participants, are a type of interview “where the prime concern is to encourage a variety of viewpoints on the topic in focus for the group” (Kvale & Brinkmann, 2009, p. 150). The researcher’s role in focus groups is to act as a moderator to create a comfortable atmosphere in which different views are welcomed and respected (Kvale & Brinkmann, 2009). Although focus groups are access to a variety of perspectives at one time, there are concerns which must be addressed. Students may be less likely to contradict a classmate’s opinion or statements for the fear of being different. Kvale and Brinkmann (2009) describe the interviewer craftsman as knowledgeable, structuring, clear, gentle, sensitive, open, steering, critical, remembering, and interpreting (p. 166-167). These qualifications were addressed before and after interviews and focus groups in a reflexive journal as I assessed my participation in the research process.

Over the course of the study, each student was interviewed either individually or in focus groups at least once. I kept a record of focus group and interview participants, and attempted to engage each student, particularly during focus groups. By doing this, my hope was to equalize students’ feelings of “importance” in the study. I did not wish for any student to feel left out or less engaged than their fellow classmates. Likewise, I did not want individual students feeling more important than their classmates.
Observations. During this study I took the role of an observer-participant, as I remained “primarily an observer but [had] some interaction with study participants” (Glesne, 2006, p. 50). My very presence may have affected the teachers’ instructional methods or the students’ behaviors. Likewise, engaging with the students during observations was unavoidable. Descriptive and analytic observation data was recorded in the form of field notes, and then analyzed and expanded as soon as possible after leaving the classroom, typically on the same day (Glesne, 2006).

Data Collection

Data collection consisted of classroom observations, a minimum of three days a week over a period of five to six months as the participants’ schedules permitted. A sample observation protocol can be seen in Appendix E. The purpose of classroom observations was to explore the presence and enactments of multiliteracies, science and scientific practices, and varying levels of student voice. In addition, based on classroom observations, data was also collected through teacher and student interviews to investigate their perceptions of multiliteracies, science and scientific practices, and student voice in the classroom. I also used interviews and focus groups to explore or clarify areas of interest observed during classroom observations such as specific instructional methods, tools used, and communication methods. Student focus groups provided data on students’ social interactions from their perspective. Focus groups also allowed me to interact on a personal level with the students as I prepared to choose individual students for in-depth interviews. Interview and focus group data was audio-recorded, video recorded, and transcribed. Although videotaping student interviews is not a frequented practice, I believe that student voice can only be fully captured and respected through a
combination of visual and auditory data. Variables such as body language and volume are important components of accurately portraying student voice.

Artifacts (such as student work, texts, and other appropriate items) were photographed and carefully examined in order to further enhance the trustworthiness and richness of the overall data (Marshall & Rossman, 2011). Memo-writing and reflexive journaling were also utilized in order to “remain transparently grounded in the lives of those who constructed the data—the participants and researcher” (Mills, Bonner, & Francis, 2006a, p. 11).

Glesne (2006) defines reflexivity as being just “as concerned with the research process as you are with the data you are obtaining” (p. 125). Research with children as participants requires constant attention to representation and power relations. By keeping a reflexivity journal, I forced myself to pay attention to these power relations which in this study are related to student voice. Through reflection on self, I was able to analyze the questions I asked during interviews and focus groups, and examine how my personal beliefs were impacting data analysis.

Maintaining the constructivist view that knowledge is socially constructed while attending to student voice which is inherently intimate in nature, I chose to collect data regarding voice in three separate ways: as a whole class, in small groups, and individually. By doing this, through classroom observations, interviews and focus groups I was able to analyze voice from a large social context to the individual context.

**Focus one: Classroom voices.** Initial interviews with Ms. Randall and Ms. Tyson were conducted with the purpose of gaining insight on their teaching philosophies and perceptions of scientific practices, student voice, and multiliteracies in the elementary classroom. Teacher interview protocols can be seen in Appendix F. Fifty minute classroom observations focused on
the enactments of scientific practices, student voice and multiliteracies were completed up to five times a week during this phase. Although I originally planned on spending several days each week in each class, two variables required a change of plans. First, Ms. Tyson and Ms. Randall taught science at the same time in the afternoon. Second, Ms. Randall was mentoring a student teacher intern. Because I did not have IRB approval to observe the student teacher, nor would observations of her teaching really address my research questions, I chose to spend the first two and a half months primarily in Ms. Tyson’s class. When Ms. Randall’s student teacher was relieved of her responsibilities of teaching science, I returned to Ms. Randall’s class four days a week. However, although I did not visit Ms. Tyson’s class as frequently in the afternoon during “science time” at this point, I was able conduct observations during “math time” as they began an engineering project. After five months, records indicated 20 observation hours logged in Ms. Randall’s class and 30 observation hours logged in Ms. Tyson’s class. Classroom observations were recorded as field notes and memos which were examined for teaching strategies or episodes that specifically address the key questions of the study.

Focus two: Social voices. During this phase, observations continued as the focus targeted student dynamics in the classroom with the intent of analyzing the social aspects of voice, multiliteracies and scientific literacy. Focus groups as a method are “socially oriented, studying participants in an atmosphere that is more natural than artificial experimental circumstances and more relaxed than a one-to-one interview” (Marshall & Rossman, 2011, p. 149). By interviewing students in focus groups during this phase, I was able to question the group of students in a stress-reduced setting while maintaining the idea that the students’ views of scientific practices, multiliteracies, and student voice are socially constructed. Five focus groups were conducted in Ms. Tyson’s class, while four focus groups were conducted with Ms. Randall’s students. Focus
group protocols for Ms. Randall’s class are located in Appendix G, while protocols for Ms. Tyson’s class are located in Appendix H. I limited the focus groups to no more than five students at a time. The open-ended questions during the focus groups encouraged students to build upon each other’s responses. My experience with students in this age range gave me the confidence to conduct a student focus group with openness and trust while encouraging discussion from all members of the group. Through reflection on the observations and focus groups, I also selected two students per class for Phase III. Teacher interviews were also conducted during this phase to address questions that emerged from observations.

Focus three: The student voice. This final phase required an in-depth look at individual students. Four students were chosen for individual interviews through purposeful selective sampling (2 per class). Maintaining a constructivist approach to grounded theory, the specific criteria for selecting individual students for this phase was determined during the first stages of data collection and analysis as categories arose and warranted further exploration. Although I chose students from varying ethnicities, ability levels, socio-economic statuses, and gender, as Stake (1995) notes, “balance and variety are important; opportunity to learn is of primary importance” (p. 6). The four students chosen—Callie, Kevin, Aaron, and Gabriella—were selected because they represent four very distinct voices. Each student will be described further in the following chapter.

During this time, I continued observations, focusing on the individual students as opposed to the group/class. Three interviews were conducted with Callie and Kevin from Ms. Tyson’s class (see Appendix I), while two interviews were conducted with Aaron and Gabriella from Ms. Randall’s class (see Appendix J). The interviews delved into the students’ personal views of student voice and multiliteracies in science. Data collection concluded with one final
teacher interview focusing on questions that address specific areas of interest observed during the study.

Eliminating stress during focus group interviews and in-depth interviews with students was an important consideration, particularly because the interview and focus group protocols addressed the students’ perception of their voice in the classroom. “Interviewing is a process where interviewer and interviewee through their relationship produce knowledge” (Kvale & Brinkmann, 2009). Referencing Eder and Fingerson (2002), Kvale and Brinkmann (2009) outline the issues confronting interviewing children, “the power imbalance between the child and the adult, and the need for the interviewer to avoid being associated with the classroom teacher, as well as to refrain from conveying expectations that there is one right answer to a question” (p. 146). Power relations are unavoidable when working with students, but I attempted to make the students feel as comfortable as possible during the research process. For example, I tried to not hold side conversations with the classroom teacher in front of the students as to not be associated with other authoritative members of the school staff that may do such a thing. Nor did I want the students thinking that I was sharing their personal information shared in interviews with the teacher.

Data Analysis

All individual interviews, focus group interviews, observation field notes, and researcher memos were transcribed verbatim as quickly as possible following the initial data collection. This process is “amenable to closer analysis, and is in itself an initial analytic process” (Kvale & Brinkman, 2009, p. 180). The transcribed interviews were read multiple times and then coded for various themes—multiliteracies, student voice, and scientific literacy. Beginning with “initial
coding,” I worked to quickly code each piece of data line-by-line, attempting to focus on the “language of action” rather than theoretical topics (Charmaz, 2006, p. 47). This step kept the data honest and focused on the participants and their perspectives, rather than my own (Charmaz, 2006). I then moved to a more “focused coding” where I coded larger sections of data as themes emerged (Charmaz, 2006, p. 57).

An integral piece of grounded theory analysis is the use of memo-writing as a way to develop and consider codes throughout the research process (Charmaz, 2006; Glesne, 2006). Recording thoughts about the data led to the development of new ideas which needed to be addressed in data collection. Charmaz (2006) suggests using memo-writing as a time to define codes, identify gaps in the data and in the analysis to make comparisons between data sets (p. 82).

While keeping an open mind about what is observed in the classroom, it was helpful to outline some general characteristics of multiliteracies, scientific practices, and student voice that may have been present in the classroom. Multiliteracies could be implemented in the use of technology, visual literacy, multimodality, or perhaps through the four pedagogical practices outlined by Cazden (2000): situated practice, overt instruction, critical framing, and transformed practice. The eight NGSS scientific practices of interest are as follows:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking

6. Constructing explanations (for science) and designing solutions (for engineering)

7. Engaging in argument from evidence

8. Obtaining, evaluating, and communicating information (NGSS Lead States, 2013c, p. 1)

Very few published research articles explore student voice in the elementary classroom setting. In this study, analysis of student voice during each phase varied as the social context varies. However, particular attention was given to why and how students communicated with the teacher and with their peers.

As is typical with a grounded theory approach, data collection and analysis were constant and ongoing throughout the research process (Charmaz, 2006). Although all grounded theory is somewhat constructivist in nature, this study seeks to deliberately assist teachers and students in chronicling their classroom experiences with multiliteracies, student voice, and scientific practices. Delicately encouraging students to describe their experiences and the social processes that emerge while constantly immersing myself in the data allowed for analysis that elevated the students’ accounts to a theoretically rich level.

All data (transcripts, scanned documents, audio recordings, video recordings, and photographs) were put into and stored in ATLAS.ti Version 6.2 (2011). Similar to the traditional hand-written method of coding specific quotations were identified and then labeled with researcher-generated codes.
Data analysis for this study began with initial coding (Charmaz, 2006) which resulted in specific codes such as “Observation (Obs)- Reading from Textbook,” and “Student- Textbook Image Opinion.” As I re-coded data during the data collection and analysis process, I continued with focused coding (Charmaz, 2006) as I modified codes, double-coded passages, and developed broader categories such as “Visual Literacy” and “Scientific Practices.” For example, in a particular passage, the initial code “Obs-Reading from Textbook” was also double-coded with “Obs-Scientific Practice-Asking Questions-Textbook” and “Obs-Visual Literacy-Textbook.” In a sense, I was linking subcategories to broader categories while organizing data and making connections (Charmaz, 2006).

**Trustworthiness**

Glesne (2006) references Hollway and Jeffeson (2000) when she lists four key questions that researchers should address when considering the trustworthiness of their work:

1. What do you notice?

2. Why do you notice what you notice?

3. How can you interpret what you notice?

4. How can you know that your interpretation is the “right” one? (2006, p. 166)

In order to answer these questions and increase trustworthiness of the work, several procedures were implemented during the research process including triangulation of data, member checking, researcher reflexivity, and peer debriefing (Marshall & Rossman, 2011). Through interviews, focus groups, classroom observations, and artifact analysis, data source triangulation was implemented throughout the study contributing to a vast data corpus (Stake, 1996). Data
collection and analysis continued until the data was saturated and new themes ceased to emerge (Charmaz, 2006; Marshall & Rossman, 2011). To assist in trustworthiness of data analysis, peer-debriefing was implemented periodically during all stages of data analysis. Member-checking was implemented with the teachers, though not with the students.

**Summary**

This chapter provides the methods for investigating scientific practices, multiliteracies, and student voice while adhering to a constructivist framework. Set within a fourth and fifth grade elementary classroom, data were collected through a variety of methods that include interviews, focus groups, observations, and informal conversations. Observations occurred several days a week through the entirety of the study. Teacher interviews were conducted strategically using interview protocols developed as categories and themes emerged. Student focus groups were conducted as a way to gain insight into the social nature of student voice, multiliteracies, and scientific practices. Finally, four students were selected through selective sampling to interview individually. Through a grounded theory approach, data was analyzed consistently throughout the study through coding and memo-writing.
CHAPTER 4—FINDINGS

Chapter four narratively portrays findings from the classrooms of Ms. Tyson and Ms. Randall. As a collective case study, the findings as related to multiliteracies and science are rich in detail and presented individually for each teacher. The narrative begins with a description of the school setting in which both teachers work and then continues into each teacher’s classroom. The narratives then take an in-depth look at teacher and student perceptions of multiliteracies, student voice, and scientific practices.

School Setting

Littleton Elementary is located in a small school district adjacent to a large, southeastern urban area. The student demographic breakdown is 2% Asian, 21% African-American, 10% Hispanic, and 66% Caucasian. Littleton is a Title I school, consisting of 610 students of which 29% receive free or reduced lunch. The neighborhood in which the school is located has a median home price of over $430,000—higher than 99.5% of the neighborhoods in the state (Location, Inc., 2014), as such the socioeconomic diversity is a unique characteristic of the school.

Given the socioeconomic and cultural diversity of Littleton Elementary, the school district’s motto was broadly displayed. “The mission of the Morning City Schools was to educate and empower every student to reach his or her unique potential.” This mission was posted on the district website, as well as the Littleton Elementary website. Littleton’s school motto was also
visible throughout the school. The Littleton Way, as posted on the website and displayed throughout the school is as follows:

Listen to others…and they will listen to you.

Avoid put-downs…who needs them?

Take charge of yourself…you are responsible for you.

Show respect…everyone is important.

Have fun…life is a gift.

Littleton is one of three schools in the state identified on “The Whole Child” website (ASCD, 2014) as a school in which the “whole child approach” is being implemented in an exemplary way. The school is also one of the Character Education Partnership’s (CEP) National Schools of Character (CEP, 2014). It was not surprising then, that when walking through the halls I felt as if the school had a gentle atmosphere. There was never a great deal of noise, even when students worked on projects or read on the carpeted hallway floors. I was greeted warmly each day by multiple members of the school staff including custodial staff, administration, and classroom teachers. During the five months I observed in the school, I felt welcome every day.

Built in 1920, the school maintains original architecture reminiscent of an earlier era with a brick exterior, wooden entryway doors, and many white-framed windows. Colorful student work lined hallway walls outside each classroom. Further showing the students as valued members of the community, Digital Citizenship posters were also posted on hallways throughout the school. I was quickly introduced to an important platform for developing multiliteracies utilized in Littleton. Throughout the district there is a “Bring Your Own Device” policy, and from my observations, many students embraced the policy by bringing their own technology.
Students were encouraged and took advantage of readily available laptop computers on carts located in the hallways of each grade level. From my observations, it appeared that the climate of Littleton’s Elementary School was one that valued teachers and students, much like that of a learning community where each voice has something important to contribute. Given this context, the classrooms of Ms. Randall and Ms. Tyson are presented in light of the study’s focus on multiliteracies, student voice, science, and scientific practices. The case descriptions of Ms. Tyson and Ms. Randall begin with descriptions of their background and teaching styles, and continue with an exploration of their perceptions of multiliteracies and student voice. These discussions address the teacher portion of the research question, “What are teacher and student perceptions of multiliteracies, student voice, and scientific literacies?” Because the participants’ discussions of multiliteracies and voice were primarily centered around science, scientific practices will also be discussed throughout the chapter.

Ms. Tyson’s Science Class

“Traditional”—With a Splash of “Hands-On”

Ms. Tyson is in her late twenties and in her fifth year of teaching, with all five years in fifth grade at Littleton Elementary. The physical décor and layout of Ms. Tyson’s classroom appears as one that might be designed as a transitional room between elementary and middle school, striking a balance between child and teen. For instance, the room was neither overly colorful nor bare, but each space seemed to be utilized efficiently (as often seen in middle grades). Students even kept their backpacks in lockers located in the hallway rather than in the classroom as seen in many elementary schools. The nice-sized room also had a couch and bookcases which defined a reading space in a back corner (often seen in elementary classrooms).
There were several posters on the wall (informational), iPads and tablets charging on the back counter, and student desks arranged in groups of five. Science was the last subject taught during the day, typically from 2:05 p.m. to 2:50 p.m.

According to Ms. Tyson, the fifth grade team of teachers rarely planned lessons together as a whole, though Ms. Tyson expressed comfort with sharing activities with one other teacher, Ms. Caldwell. She and Ms. Caldwell typically “stay on task with each other,” using shared lesson plans whereas she believed the other teachers do not “have any lesson plans and just know what they are going to do.” She also admitted that the other teachers, who have many years of teaching experience, have different teaching styles, “They’re great teachers and they always have great test results. The kids love them. But we do teach in different ways.” This was not the only time that Ms. Tyson mentioned directly or indirectly the importance of test scores.

I was curious about the “differences” in teaching styles to which she was referring when describing her grade level teacher team. In the following exchange, Ms. Tyson and I both used the term “traditional” to describe a teaching style. Traditional teaching is often associated with a teacher-centered or transmission approach to teaching and learning where information is passed from teacher to student (Richardson, 1997). In practice, traditional forms of education may include lecture and other teacher-centered activities as opposed to more constructivist, inquiry-based activities (Richardson, 1997). I asked if she considered the other more experienced teachers more traditional and she responded by saying, “I don’t know, because I think Ms. Caldwell and I are pretty traditional…We have more lesson plans and group work and more hands-on activities than they use.” This was a bit surprising and not the expected description of traditional teaching. It did, however, provide insight into Ms. Tyson’s personal teaching style of “traditional” which included the integration of group work and hands-on activities neither of
which is the typical view of “traditional” teaching. This was an important detail as she identified former teachers as the most influential factor in her current teaching style.

While describing influential teachers and her learning preferences, she also revealed her views on teaching through inquiry:

I know a lot of [teaching science] is gearing toward teaching yourself now [student-center inquiry], but for me I think that’s very difficult. And I know it’s a little controversial, but I think it’s hard sometimes to teach yourself something you don’t understand. And if you don’t understand it, you have to go more into researching it and [to] understand and you get more behind, more and more behind on other things. Which is great in an ideal world but when you’re in a time crunch it makes it a little difficult.

Although she did not use the term “inquiry,” the scenario she described of “teaching yourself” reflects the general premise of exploratory, inquiry-based learning in which students utilize scientific practices and process skills to describe, solve, and answer questions on their own (Goldston & Downey, 2013). Ms. Tyson’s statement reveals her struggle with the use of inquiry teaching practices, which may be due to her own struggles with learning that way, as well as her view of herself as traditional constrained by time limitation concerns. Ms. Tyson continued by outlining her preferred learning style:

So I liked that teachers would tell me the information though, and tell me and teach me in a fun interactive way, but yet still allow [pause] and I was able to do hands-on projects to reinforce that work.

She indicated that her former teachers influenced her teaching. Her words sound as if she perceives that students’ learn as she learned with inquiry or “teaching yourself,” which is not
necessarily the case. Stigler and Heibert (1999) contend that although teachers take part in teacher education programs, many of their teaching practices are learned from “simple cultural participation,” as they spend many years as students themselves (p. 83). Ms. Tyson described her favorite teacher as being “very interactive” and encouraging “hands-on stuff,” while also being “very explicit in her teaching.” This type of teaching was observed in her classroom. So I asked her, “How much of the day do you think you are in the front of the class teaching and talking, and how much time is spent with them doing other things? She responded by saying,

I’d say about half and half. Sometimes maybe, I would say very rarely though, it is more [student-centered]. Some days it might be 70/30. Most [of my teaching] is whole class. Most lessons, though, I try to cut in half. Half the time is me teaching and then [I have them] working individually half the time.

Observation data supports her statement, as she frequently began science lessons and units with class discussions or readings, followed by more hands-on experiences. When asked what teaching style of hers she thought students responded to best, she said, “Sometimes I think they get more out of me being up there and interacting with them because they stay focused. They get more off topic on their own.”

Embedded in Ms. Tyson’s explanation of her teaching style were concerns of time issues and student attention, as well as traditionally held beliefs that the students learn best by teacher-centered, transmission approaches where the student is the passive recipient of the teachers’ knowledge. Galton, Hargreaves, and Pell (2009) reported that teachers may be hesitant to shift from whole group instruction to group-based learning not only because of demanding schedules and curriculum, but because of fear in giving up control. Unlike whole-class discussion where
the teacher is in control of the conversation and student responses, group work requires teachers to relinquish some of this control to the students (Galton, Hargreaves, & Pell, 2009). Ms. Tyson’s beliefs about teaching, through her own words, reveal her cognizance of issues related to inquiry-based teaching and learning, generally collaborative in nature, while at the same time open and supportive of many of the key features of inquiry. Observations, in many circumstances, revealed a willingness to incorporate technology, inquiry, and collaboration into the classroom. However, she appears at odds with herself—dipping into the pool of multiliteracies and inquiry, but perhaps not willing to dive in just yet.

The Modern Science Classroom with Science on the “Back Burner”

When asked about her goals for teaching and learning, Ms. Tyson explained that she wants students to master content to the point that they are able to teach it to others. In the following statement, she described the role of students in her class:

I would love for [students] to motivate themselves and be their own teacher. My goodness, I tell them all the time that you master a subject when you teach it, so I would love for them to be able to teach each other and learn from themselves.

This view of students as the teacher is not consistent with her previous statement in which she believed they learn more from whole class, teacher-centered lessons. Nor is it consistent with her response when asked what she would like for her students to be able to do in science by the end of the year. Ms. Tyson’s response focused on content tied to standardized testing required by the state saying, “I would expect them to know the overall concepts of each of the different science units. We have that science exam at the end of the year.” After being prompted to consider what she expects students to be able to do rather than learn, she responded:
Okay, I expect them to be able to [long pause]. See we don’t do a whole lot of hypothesizing and experimenting and all of that. I guess group wise… we do a couple of projects in science. So they need to know how to work with a group and do group work. The predictions usually get better by the end of the year because they can kind of look though the book and predict the text.

The predictions to which referred are part of workbook pages that were used to accompany reading from the textbook. This will be discussed further in the activity portion of this chapter.

As she previously mentioned in the explanation of how she teaches science, time again appears to be a factor, but other factors are implied such as the demand to teach other disciplines during the main part of the day leaving science for the end. She stated the following with regards to planning science lessons:

I [plan] a week at a time. Science and social studies are so tough because it’s at the end of the day and those are the two that kind of get put on the back burner, especially social studies which is so sad. So that we have to be very, I don’t know the word for it. I have to change up the schedule a lot with science—be very flexible. Because sometimes we run out of time and I’ve spent more time on social studies than on science. Or sometimes they just get so off task at the end of the day and things take longer than I think they’re going to take.

Furthermore, Ms. Tyson added as I was leaving the room after this particular interview that she is also required to teach science and social studies in the afternoon because that is the designated time for fifth grade intervention. Essentially, students are pulled from her class for intervention services during science and social studies because they are not allowed to be removed from class
during reading or math. Ms. Tyson’s need to prioritize certain subjects over others, particularly reading and math over science and social studies, is not an isolated occurrence as many elementary school teachers experience the same pressures (Griffith & Scharmann, 2008; Milner, Sondergeld, Demir, Johnson, & Czerniak, 2012). Perceived issues of time management and accountability permeate through the modern science classroom, causing teachers such as Ms. Tyson to struggle with teaching science regularly and effectively.

Ms. Tyson’s class was typically a calm and quiet atmosphere. However, in later observations when the students participated in an inquiry-based investigation, the Toothpick Bridge Project, there was quite a bit action and movement in the room. However, the students in Ms. Tyson’s class behaved consistently with her expectations:

I want them to sit and listen when I’m talking. When it’s time to talk and time to experiment and time to work, they can you know, talk and move around the room, but stay focused.

Although she stated previously her concern about classroom management when students work in small groups, classroom observations support that when students worked in partners or groups, they generally stayed focused on the task at hand.

The exploration of Ms. Tyson’s background and teaching style serves to situate her use of multiliteracies, student voice, and scientific practices within the context of classroom interactions. What follows next is Ms. Tyson’s perceptions about multiliteracies which encompasses a discussion of scientific literacy and associated scientific practices, as well as other literacies identified in Ms. Tyson’s classroom.

**Perceptions About Multiliteracies**
When I first approached Ms. Tyson and Ms. Randall to obtain consent and review the purpose of this study, I asked informally if either had ever heard the term “multiliteracies.” Both teachers laughed and said that they had not. Multiliteracies by nature are multifaceted and encompass a variety of literacies and practices. Innovations in technology along with increasing cultural diversity not only allow for, but require, an evolving view of what constitutes “literacy” in today’s classrooms (Cope & Kalantzis, 2000). In turn, this new view of literacy requires a shift in K-12 instructional practices, with growing importance being placed on technology proficiency, visual literacy, problem solving, and collaboration (Cope & Kalantzis, 2000; Gee, 2000; Kress, 2003; Lankshear & Knobel, 2006). Though neither teacher could identify or define multiliteracies, I continued to explore the various components of multiliteracies enacted within their classroom and through interviews and informal conversations.

**Technology.** Innovations in technology are a foundational component of multiliteracies (New London Group, 1996). In addition to the Littleton Elementary School’s “Bring Your Own Device” policy, Ms. Tyson’s class was equipped with an overhead digital projector, Audio Visual package, digital tablet, five iPads, and a shared fifth grade laptop cart. Depending on the day, up to five students brought their own mobile device. Only one student in the class did not have the internet at home, though her mother had internet on her mobile phone. Technology was used by all and in many different ways in Ms. Tyson’s class including BrainPop (2015) videos, Science Court (Scholastic, 2015), Schoology (2015) assignments, and online research. These applications and programs are described in detail later in this chapter. The technology application components of multiliteracies, in addition to the utilization of technology hardware, engaged students through multimodal instruction, problem solving, and peer collaboration (Cope & Kalantzis, 2000; Lankshear & Knobel, 2006).
Although she instituted a variety of technology activities, Ms. Tyson still believed that her use of technology was lacking compared to other teachers. She appeared to struggle between wanting to use technology more frequently while at the same time wary of implementing tools and practices inefficiently. She said, “I use it as more of an aid, than as a dominating factor. I would love to be better at it and be able to apply it more. Sometimes I feel like teachers use technology just to use it.” She also outlined several technological concerns she had including relevance and logistical issues in the following:

I will admit that it gets kids more into things sometimes, but the whole process of going to get a laptop, turning it on, logging in, and getting the kids where they need to be just so they can type a paper every single time, takes a very long time. Now I think it’s very important that they know how to type a paper, but that’s just one example of course. We complain about that all the time. iPads are so quick, you just get them and turn them on. If we had quicker resources than going all the way down the hall and getting the laptop cart and making sure it’s plugged in. Logistically a lot of technology here is difficult [to get and use].

She continued, this time referring back to her personal experiences and priorities of learning:

I would love for [computers] to replace textbooks and everything. I still think that they should have the textbooks here and maybe not have to lug the textbooks home. I still think they need to know how to do [use] a table of contents and dictionaries. You know, the ways that we’ve grown up in. But I think that’s all starting to be replaced so they need to be kept up to date.
In her ideal situation, she would give each student an iPad and attachable keyboard, as she believed it would alleviate some of these problems. Even with admitted hesitations, she still believed that students benefited from using technology in classrooms because of its potential for more engaging activities and as an alternative tool for learning, “I think it gets them more excited about it. Definitely. I think it gives them another way to learn and another voice to hear besides mine.” In this instance, Ms. Tyson used the term “voice” in such a way that it appears to refer to another source of authority or source of knowledge. This implies that when implemented into the classroom, technology has the capability to serve as another voice or resource authority in addition to the students and the teacher.

Ms. Tyson also believed students are enthralled with the novelty of iPads, while unsure of whether or not students learned more through iPad use or traditional methods. She stated, “To be honest I don’t think it necessarily is anything to do with [pause] I don’t think just because it’s an iPad they’ve learned any more. I think it’s something new and exciting.” She identified iPads and computers as a quick resource tool for expanding and elaborating upon questions during lessons while stating earlier that it takes time to efficiently use them. She voiced,

I like the fact that if we have a question and we’re reading the textbook it’s more difficult to find it. On the IPAD we just have to type it in and we can figure it out. It’s an easy tool to use to research and further knowledge.

Ms. Tyson’s modus operandi with technology is “quick.” She demonstrated the use of iPads for quickly researching information in both teacher-directed and student-initiated ways. Students were asked on several occasions to complete online researching assignments. Students, however, also used iPads and other mobile devices during other classroom activities without being
prompted by Ms. Tyson. Being able to utilize technology flexibly is a key feature for technology components of multiliteracies. Ms. Tyson’s implementation of technology use in her classroom also engaged students in the scientific practices of Asking Questions and Obtaining, Evaluating, and Communicating Information (NGSS Lead States, 2013c). Open access to technology was an accepted practice in Ms. Tyson’s classroom that supported scientific literacy and students’ ability to engage in this scientific practice. Observing students use technology, Ms. Tyson recognized that her students were incredibly comfortable with it. She stated, “I think they know a lot more about technology than we do.” Students in focus groups confirmed her supposition stating that they were self-aware of their own skill and ability with technologies available to them.

Ms. Tyson saw technology as more of a tool for consuming information instead of creating it. Despite this, she captured a key point of multiliteracies. She reflected,

It’s really hard because we’re teaching them to use a technology that’s probably going to be extinct in ten years, so you have to teach them skills that gets them used to new technologies. […] I think the most important thing to teach them is inquisitiveness. Not seeing, like I do a new technology and getting intimidated by it, but wanting to put their hands all over it and wanting to touch it. I think it’s not even technology, it’s knowledge in general.

Ms. Tyson recognized that innovations in technology require a new way of thinking that is not solely focused on the technology itself, but rather the affordances allowed by the technology (Knobel & Lankshear, 2008, 2009; New London Group, 1996). This view is consistent with the knowledge building concept in which students are encouraged to be self-aware of their thinking, creating a learning culture of knowledge rather than transmission and consumption (Scardamalia
& Bereiter, 2006). This statement also implies that Ms. Tyson values the importance of fostering and developing students’ creativity and inquisitiveness. Many of the NGSS scientific practices are associated with or encourage this type of inquisitiveness, including Asking Questions, Developing and Using Models, Planning and Carrying out Investigations, and Constructing Explanations (NGSS Lead States, 2013c). Ms. Tyson’s statement suggests that students benefit when scientific practices and technology are used in support of each other. Another aspect of multiliteracies, peer interaction or student collaboration, in Ms. Tyson’s classroom is portrayed in the next section.

**Student collaboration.** An important component of multiliteracies is the ability for students to work flexibly and adaptively in a variety of situations with a variety of people. These skills create what Gee (1994) calls a “portfolio person.” In elementary classrooms, working collaboratively with others gives students a chance to practice and develop these skills. Through these collaborative interactions, students’ voices are given the opportunity to be heard and developed by their peers. Ms. Tyson’s view of collaborative learning in her classroom was framed by her perceptions of student maturity and responsibility in this particular grade level seen in the following. She said,

> I feel like at this age, 10 and 11 years old, more than any other age group, they are starting to get so much more concerned with socialness and you know just getting off task with friends and liking boys and girls.

In spite of her concerns and insights on her students, she expressed her willingness to assist students to grow as collaborators in the classroom. For instance, she stated,
Especially with this age group, maturity level wise, a lot of them are at the curve where some of them are starting to get it. Some of them are still so immature, so it’s that balance between maturity—you know and being able to handle group work right now. Some of them can’t. We try and we learn and we really work on group work. What it takes to be a good group member, but it’s hard. It’s hard at this age.

Just as she expressed dissonance about the implementation of inquiry and technology, she also admitted that she would like to allow more student interaction in her class. However, her expectations for classroom management appear in opposition to her desire to give students freedom to explore.

I would love it if I trusted them more to have more interaction and group work and movement around the room. It’s really hard when you have, and I know I have a smaller classroom, but managing. [It is a balance between] classroom management versus freedom to explore and learn themselves.

Ms. Tyson verbalized discomfort in implementing student collaboration in her class because she felt students lacked maturity levels to handle it therefore leading to classroom management issues. However, she continued to implement classroom practices that required varying levels of collaboration among students from simple group work where students read an article together to complex collaborative learning as observed with the Toothpick Bridge Project. As students worked together, Ms. Tyson worked to create a climate where respect and appreciation for each other’s similarities and differences have the capability to grow. She however, continued to struggle with allowing them opportunities to collaborate. In the following section, a side of Ms. Tyson comes through that celebrates learning and diversity.
Student diversity. In addition to advances in technology, multiliteracies also emerge from the increasing linguistic and cultural diversity of today’s societies (New London Group, 1996). This diversity is accentuated by the potential to communicate with global cultures through the Internet. Ms. Tyson had very little to say on the topic of globalization as a result of technological advances despite the socioeconomic diversity of the school that spans from the very wealthy to high poverty. She did however, express joy in working with students from varying linguistic and socioeconomic backgrounds at Littleton Elementary School. In fact, she expressed it was one of the most exciting things about teaching:

I love it. I know that’s probably a typical answer. I love it. Now it’s less exciting when [the higher achieving students] get it because things click with them all the time. But when I see Perry, Luis, or Maria, have something just click and they got it…in my heart I’m like “Yes!”

One afternoon, Ms. Tyson even gave Maria a chance to sing the popular song from Frozen, “Let it Go,” in Spanish for the entire class. Maria sang the song beautifully, a cappella, and seemingly without nerves. Afterward, the class stood up and applauded. Maria’s impromptu performance is a testament to a classroom environment in which students respect each other’s differences and feel comfortable being themselves and sharing their voice, literally and figuratively with others. This openness to others means being open to other cultures and is a necessity in developing multiliteracies not only because of the diversity of local societies, but because of the global connectedness afforded by the digital technologies and specifically the Internet (Cope & Kalantzis, 2000).

Perceptions of Student Voice
Unlike multiliteracies, student voice was a bit more difficult to explore in teacher interviews, particularly because I did not want to influence Ms. Tyson’s teaching through my questioning. Littleton Elementary is identified as a school in which the “whole child” is nurtured (ASCD, 2014). ASCD identifies five tenets that summarize their Whole Child Initiative:

1. Each student enters school healthy and learns about and practices a healthy lifestyle.
2. Each student learns in an environment that is physically and emotionally safe for students and adults.
3. Each student is actively engaged in learning and is connected to the school and broader community.
4. Each student has access to personalized learning and is supported by qualified, caring adults.
5. Each student is challenged academically and prepared for success in college or further study and for employment and participation in a global environment. (ASCD, 2013)

These tenets reflect aspects of multiliteracies and student voice research, including the need to personalize education to empower individual students while at the same time giving students the opportunity to connect with their peers and the broader world (Collins & Halverson, 2009; Cook-Sather, 2006; Dimick, 2012; Robinson & Robinson, 2013; Wade, 1995). Because Littleton Elementary is identified as a Whole Child school, discussing the Whole Child opened Ms. Tyson’s views of student voice in a way that was familiar. The following is centered on a snapshot of her definition of the whole child, as well as her feelings of achieving the goal of actually teaching the whole child:

Hmmm [pause] the whole child [pause] I would say the whole child is not only educating them on what they’re good at but diving into all areas, I would say not only basic school
stuff but working on their character, working on their group work, and their socialization.

I would say the whole child is their whole personality, their mind, body, and soul.

When asked if she believed teachers were successful in teaching “the whole child,” she responded again with perceptions of limited time and autonomy:

No, I don’t [think teachers do a good job teaching the whole child]. [pause] I think that is another idealistic term. Teachers are only given a certain amount of time and they’re given a lot of material and subjects to cram in. I don’t know how you’re expected to educate the whole child and teach the whole child when teachers are overwhelmed.

Similar to the other topics discussed, time and other teaching requirements were revealed again as limitations for Ms. Tyson, including her ability and willingness to incorporate collaborative learning. She felt accountable for meeting a daunting number of academic standards, while at the same time wanting to be more in-tune with students, their personal lives, and interests. In an informal conversation, she revealed that she used to enjoy conducting one-on-one conferences with the students periodically throughout the school year to discuss topics that were not entirely academically-related. She felt that she learned a great deal from her students during the conference. Recently, though, she did not conduct the conferences because she felt there was not enough time. She has removed from her classroom what she believed to be an integral piece of building relationships with her students due to her perceived lack of time.

In Ms. Tyson’s interview data, time constraints and an overload of standards and responsibilities emerged frequently across several topics. In addition, Ms. Tyson appeared unsure and internally vacillating on several topics. For instance, she felt a desire to incorporate technology more frequently in her class, but believed that logistically it was not always an
effective option. She believed that collaboration is important, but she felt that students in the fifth grade sometimes lacked maturity to work productively in groups. She would like to spend more time addressing students’ emotional needs as well as academic, but feels that she lacks the time to do so. In the following section, the perceptions of Ms. Tyson and her students are explored in relation to the multiliteracies and science activities observed in class.

Classrooms Experiences: From Both Sides

Classroom activities frame the lived experiences of its participants, Ms. Tyson and her students. Therefore, this section takes an in-depth look at Ms. Tyson’s classroom science activities with a focus on multiliteracies, student voice, and scientific practices. This discussion addresses all three research questions of this study:

1. What and how are multiliteracies, science, and scientific practices implemented in the elementary science classroom?

2. With respect to learning science and scientific practices in the classrooms of study, how are student voices engaged through multiliteracies?

3. How do teachers and students perceive multiliteracies, student voice, science, and scientific practices as they are enacted in the classroom?

Furthermore, focus group data, as well as data from Kevin and Callie, provided additional insights into the activities and interactions creating a more holistic perspective of the classroom experiences. The classroom activities presented demonstrate an array of student interaction, with peers, science content and scientific practices advocated in the NGSS (NGSS Lead States, 2013c). Multiliteracies, in the forms of visual literacy, student collaboration, problem solving
and flexibility, and interactions with multiple technologies were identified. Within the narrative, enacted scientific practices are identified next to activities in parentheses so that they can be discussed later in Chapter 5.

**Kevin and Callie: What do I think?** In addition to student focus groups, Kevin and Callie were interviewed individually as a way to explore student perceptions more intimately. Below, Kevin and Callie are described briefly to provide a background context for interpreting their words as participants in Ms. Tyson’s classroom.

**Kevin.** Kevin is an African-American male in the fifth grade that self-identified as an auditory learner and wants to be a musician when he grows up. Class observations revealed that he was quiet and rarely participated during whole group instruction, though he was more conversational during small group activities. Though quiet, he occasionally raised his hand to answer teacher questions. During interviews he often made comments that spoke to his lack of confidence in science and math by saying, “I’m not good in math” and “I don’t feel I do stuff right all the time.” He was gentle in nature, and smiled frequently. He loved playing video games, music, and spending time with his family. When asked what he was interested in other than music, he replied, “Working with my dad. We work outside. We clean up our yard because we have these two big woods and we have to go around and pick up balls that we throw down there.” More than most students in the class, he was reproached by the teacher for not paying attention. He was frequently told to “pay attention” and “put your pencil down.”

**Callie.** Callie, a Caucasian female, in Ms. Tyson’s fifth grade class is identified as gifted and attended the “enrichment class” one day during the week with the other gifted students in her grade. She was always eager to answer teacher questions, but did not come off as a “know it all”
because of her curiosity and propensity to ask questions almost as much as she answered them. Even in our interviews she liked to discuss science content that interested her. For instance, when I asked her about her favorite science topic she said, “Oh, it’s elements and matter…I just always like elements and atoms. I think they’re really cool—just how they work.” She was noticeably excited when talking about science in our interviews, just as she was when answering questions in class.

In small groups she listened to her peers and attempted to explain and help when they lack understanding. She gave her peers positive affirmations. For example, during Science Court, she assisted an English Language Learner (ELL) in her group by pointing to sentences and words that she believed needed to be highlighted in the reading selection. In general, she found positive attributes among her peers. However, during the Toothpick Bridge project she grew quite frustrated with one member of her group. She called him “argumentative” and openly expressed her difficulty in working with him. Though not completely sure, when she grows up, she may want to be a lawyer. In the following discussion of classroom activities, the voices of Kevin, Callie, and their classmates are presented as insights into student perceptions of multiliteracies, student voice, and scientific practices.

**Reading in science—Teacher questioning, teacher/student dissonance, and visual literacy.** The first five observations in Ms. Tyson’s class consisted of students reading a variety of passages from their textbooks and other teacher-selected materials. Three of the lessons utilized student workbook pages that accompany the science text. Before reading the lesson (either in pairs or as a whole class), students self-assessed their prior knowledge by reading several statements, and then agreeing or disagreeing with the content.
When reading aloud as a whole class, Ms. Tyson chose the first reader and then the students were allowed to “popcorn” the reading to another student at any point. Some students read entire paragraphs while some only read a few sentences. Ms. Tyson believed that the students enjoyed this method. She said,

They actually like it. When I first started I was afraid. I didn’t want to call kids out and make them nervous. I was always one that was like, oh my gosh am I going to get drawn? They love it. They get disappointed when they, like one of them yesterday said my popsicle stick is never drawn. I was like, I’m sorry. That’s why they like popping so much.

Callie, on the other hand, expressed her views with whole group reading a bit differently, “I think it’s a little boring because I can read ahead really quickly while the rest of the class is talking about it. I’ll be like reading ahead and they may catch up.” In a focus group, several students expressed views that aligned with Callie’s with respect to reading their textbook:

Tyler: I don’t like reading our textbook because it’s just not as fun and I usually like things that are fun to read. It’s more just dissecting owl pellets and doing chemicals. Like in third grade we didn’t really read from our textbook.

Robbie: We experienced it.

Kevin: I would just, in reading, I wouldn’t read in a group. Well I always want to work alone in reading because I can read faster and concentrate.

Although Ms. Tyson expressed that students enjoyed reading aloud in class, the students in focus groups and interviews stated otherwise. Participating in focus groups with an “outsider” may
have provided a safe space for students to be more honest and open about their perceptions of classroom activities.

While reading aloud, Ms. Tyson frequently utilized pictures, charts, and diagrams in the readings to prompt questions and class discussions, this practice provides students opportunities to develop visual literacy within science. Another prominent aspect of Ms. Tyson’s pedagogy was her continued questioning in science class, regardless of the activity being completed. In one lesson, students were asked to analyze a water cycle chart. She pointed out,

Look at the chart. Technically we can start everywhere, why can we do that?

Student response: “Because it’s a cycle and it doesn’t matter [where you start].”

In another lesson, Ms. Tyson asked the students to “Picture Preview” the chapter, “Look at the pictures, look at the captions.” Again as students read aloud, Ms. Tyson intervened and directed students to look at the chart entitled, “Types of Precipitation” while saying,

Put your finger on freezing rain. What happens to freezing rain?

Student response: “It melts and then goes through a patch of cold atmosphere.”

What does that cold atmosphere do the water? Someone raise your hand and tell me how freezing rain is different than sleet.

Similar to the discussion of common teacher practices with graphics by Coleman, McTigue, and Smolkin (2010), Ms. Tyson primarily employed “pointing out” techniques when referring to graphics, rather than encouraging students to use the illustrations in other more elaborative capacities (p.629).
Although the use of graphics in the textbook encouraged student focus during readings, Callie believed that the best instructional pictures come from the Internet. When asked her opinion on the pictures of matter in her textbook, she responded by saying, “Some of them are [good], but most of them are examples of things that have matter and you kind of already know that because everything [is] matter.” Another student, Sarah Ann agreed, “Sometimes the pictures don’t really help. Like when you’re trying to do your work. Some of the water cycle ones didn’t really help.”

Visual literacy was not only addressed in print, but multimedia content as well. Ms. Tyson showed short videos (Brain Pop and Bill Nye) in addition to reading selections, usually before or after the reading portion of the lesson. Students enjoyed the videos as an alternative to reading as stated by several students seen in the following:

Robbie: I like watching videos.

Kevin: Since I’m an auditory person, I can listen to the video.

Tyler: Well, I mean, we don’t have to read the text. I can just like watch something and understand it instead of going in my textbook and having to read and all that stuff.

Tyler’s comment adds a different dimension or an alternative to Ms. Tyson’s time concerns: Is it possible that videos can cover the same amount of content as textbook readings in less time and be more enjoyable? Another group of students addressed this point.

Sarah Ann: I like videos, but I don’t want to just watch a long one. [I prefer] A short, fast one that gets to the point.

Callie: Like Brain Pop.
Sarah Ann: So they get the point, so then you could do [other things in] more interactive ways.

Sarah Ann suggests that watching short videos allow for more time to be allocated toward hands-on activities and investigations. When students were asked about their favorite science website, several students quickly responded by saying:

Kenny: Brain Pop.

Vaughn: Yeah, Brain Pop. I actually do it at my house. At my house, if I want to learn. Well it’s fun to watch and it’s educational.

Erin: It’s like fun.

Vaughn: It’s like fun, and educational.

BrainPop (2015) is an animated, online learning platform which includes short animated videos, among other tools (e.g. printable handouts, short quizzes, and teacher resources). The students in Ms. Tyson’s class supported research findings by Rosen (2009), who stated that the integration of BrainPop (2015) in science classrooms “significantly increased [elementary students’] motivation for science and technology learning” (p. 463). Furthermore, students felt as if they were more active participants in their learning and demonstrated a greater interest in science learning (Rosen, 2009). Observations of Ms. Tyson’s class revealed that the short BrainPop (2015) videos when used frequently prompted questions from the students or triggered conversations sparked from prior experiences (Scientific Practice: Asking Questions for Science). In the science reading activities that were supplemented with visuals (images and/or videos), students were more engaged in the scientific practice of Asking Questions than they
were with just reading the text alone. Being able to decode online science texts, which typically are image-heavy, while at the same time questioning and wondering are important aspects of multiliteracies and in this case, scientific literacy (Kress, 2003; Lankshear & Knobel 2006, 2009). In the next section, Science Court (Scholastic, 2015) prompts similar questioning and discourse between students in a computer-based, problem-solving program bringing to the forefront multiliteracies through technologies, collaboration, and science.

**Science Court—The convergence of multimedia in technology, collaboration, and scientific practices.** Science Court (Scholastic, 2015) is a multimedia computer software program created to “introduce core science topics and model scientific processes in the classroom—while fully engaging students with the humor of the Science Court” (Scholastic, 2015). The program, as it was implemented in Ms. Tyson’s class, consisted of a series of cartoon animation sequences followed by worksheets completed in cooperative teams which were then reviewed as a whole class activity. The animated videos chronicle a fictional trial in which scientific testimonies are used to support or disprove a claim. The program observed in Ms. Tyson’s class, “Particles in Motion,” follows a trial in which a celebrity is suing a frame maker because a very heavy, metal plaque fell out of the wooden frame onto the celebrity after being under bright spotlights during a ceremony.

The protocol followed with Science Court (Scholastic, 2015) was the same each day, and it took several days to complete the program—students watched the video segments as a class, worked on questions (worksheet) in teams, and then answered the questions as a whole class activity. In their small teams of four, each student was given a character blurb on the worksheet to read to the rest of their team. The team then answered the questions together. Afterwards, the questions were presented on the overhead digital projector and students were drawn at random to
answer the question aloud. It was stressed by Ms. Tyson that it was important for each member of the team to understand each question, because the team did not know whose name would be called to answer the question in front of the class. In this instance, Ms. Tyson’s goal of students teaching each other was fulfilled.

Science Court (Scholastic, 2015) was designed to be an engaging use of multimodal resources, with humor being a vital component. On the first day, when the students watched the Trial Part 1, 100% of the students in the class were watching the video and many laughed and giggled throughout the sequence. By the third day of the program, students swayed and snapped with the opening music. On the fourth day, as students were putting away their social studies work and preparing for science, wide-eyed Kevin looked at his neighbor and whispered, “Science Court!” and then the two high-fived.

Compared to reading their textbook (a frequent practice in Ms. Tyson’s science class), students described Science Court as a more engaging activity because of its humor. Two students often completing each other’s sentences explained:

Asia: When you’re just reading out of a textbook you’re kind of bored so you kind of…

Sybil: Doze off.

Asia: Yeah, you doze off so you’re not really paying attention. So it [Science Court] makes it funny but it’s still educational.

Asia continued:

I remember in books that are like educational. Those are like boring, you’re like okay I want to get on with this. But when you’re watching something on the screen it’s more
cartoony and funny. They [the characters] have funny voices. You kind of are like listening to what they say.

Not only did the students describe Science Court (Scholastic, 2015) as “fun,” but they also believed it to be useful for learning. Harold connected the humor to learning by stating, “I think it’s really funny. Since it’s funny you get more into it so you learn more.” Sybil and Asia point out the difference in reading the science textbook and problem solving with Science Court with Sybil starting with, “In books, they’re just like the answer is blah, blah, blah. But on [Science Court] here they help you get the answer.” Asia elaborated saying, “Yeah, you had to figure it out and it makes you get more in depth.”

With Science Court (Scholastic, 2015), students were given the chance to “figure it out” collaboratively in their team sessions. Ms. Tyson explained at the beginning of one session, “What you’re trying to figure out today is why, if both materials expand—why did one get bigger than the other?” (Scientific Practice: Constructing Explanations). In a focus group, students voiced (and demonstrated) how constructing explanations when working with peers is useful:

Asia: You can get help. So they help you out and make you understand it more.

Sybil: Like me and Asia are in a group together, and she got that particles, like in metal moved slower? [She looks to Asia for clarification.]

Asia: Metal [particle] moves, like expands faster, so the metal pops out [expands].

Sybil: But I thought that it would move faster so it just fell out.
Asia: It did say that it cracked, so it looked cracked so that made me think that the wood expanded…

Harold: Like slower?

Asia: Yeah, because if it cracks. It grew bigger and the things would have…

Harold: I just realized something. You know how if it was a perfect fit then it would only have to be a little bit bigger to crack out. So it’s still a possibility for it to crack out because it would only have to expand a little bit.

Asia: Yeah.

Sybil: But I got it, and she was different, so we just sort of like…

Asia: Explained it to each other.

This exchange between students demonstrates the intersection of multiliteracies and a key component of student voice in this classroom—peer collaboration gives students the opportunity to express themselves and their ideas in a nonthreatening way. The students in this group related to each other with such ease that they finished each other’s sentences during the focus group sessions. However, it should be noted that although this example demonstrates a scenario in which the students taught each other as Ms. Tyson would like for them to do, their understanding of particles in matter still needs further exploration and redirection.

One task from the Science Court (Scholastic, 2015) program required students to “describe an experiment that would demonstrate that one material expands more than another when heated.” This task was given several minutes of class time with several students raising their hands to contribute an answer. For example, Harold stated, “You could have two stoves
with two pans with the same temperature so the experiment is accurate and then you could put
two things in the pan and see what happens” (Scientific Practice: Planning and Carrying Out
Investigations). Although the students shared several viable ideas, none were acted upon or
explored further, despite the fact that Science Court (Scholastic, 2015) includes three additional
hands-on activity lesson plans. Ms. Tyson chose not to implement the additional hands-on
activities and describes the use of Science Court (Scholastic, 2015) as follows:

It is just another interactive tool. The kids love it and get a kick out of it. It’s kind of like
‘Magic School Bus’ where even though it’s kind of a lower grade level and interest-wise it
gives it in a way that’s easy for the kids to understand and easy to maneuver. I have
kids in 8th grade that still remember Science Court just because it stands out and it’s
different.

On the last day of Science Court (Scholastic, 2015), Ms. Tyson led the group in a lively
discussion before taking a final vote to determine the verdict of the scenario. The class was
instructed to choose guilty or not guilty given evidence presented in the trial. Before the class
voted, Ms. Tyson asked for individuals to give their opinion supported by evidence (Scientific
Practice: Engaging in Argument from Evidence). All but a few students in the class participated
in this process. Students enthusiastically, yet politely, agreed and disagreed with each other while
citing testimonies and content presented in the program. Eventually, the class voted and chose
“Not Guilty” before putting their decision into the program. One student in a focus group stated
that his favorite part of Science Court (Scholastic, 2015) was the finale. He said, “I like that it
lets you choose what the ending is.” The implementation of an interactive software program such
as Science Court (Scholastic, 2015) engaged student voices through collaborative exercises,
lively argumentation, and increased enjoyment. Furthermore, the integration of scientific
practices in this process fostered skills that are imperative in the development of scientific literacy. In the following section, student voices continue to emerge through technology as students employ a variety of online researching techniques to obtain and evaluate information.

**Researching online—Flexibility and evaluation of resources.** There were several occasions in Ms. Tyson’s science class in which students were asked to research a topic online using iPads and/or laptops (Scientific Practice: Obtaining, Evaluating, and Communicating Information). When learning about the layers of the atmosphere, Ms. Tyson separated students into small teams of three or four and then assigned each team a layer to research. They were given one science period to research and then were responsible for teaching the rest of the class about their atmospheric layer the next day, again achieving Ms. Tyson’s goal of students teaching each other. Students used iPads and laptops to conduct the research, which was self-guided as the teacher did not provide particular websites to visit.

On another occasion, Ms. Tyson presented a question for students to consider:

I have a little thing that we need to do some research on. Mrs. Pearson [another 5th grade teacher] just went on vacation and they went skiing in Utah. She noticed that it was 40 degrees, but the snow wasn’t melting. If it was 40 degrees here what would be happening to the snow? It would be melting!

Students raised their hands to make comments. One student mentioned the unusually warm temperatures of winter Olympics that were currently being held in Sochi saying, “It was warm out and people were wearing short sleeves, but there was snow there too!” Students used mobile devices and laptops to research the question, independently at first and then with their table members. Several questions arose in the process including, “Does air pressure help keep the snow from melting?” and “Does the sun’s reflection on the snow have something to do with it?”
Students also conducted research in a more teacher-directed manner when they were introduced to elements of the Periodic Table. Working in pairs, students chose and recorded information on five elements from the Periodic Table. Ms. Tyson used Schoology (2015) as a central location for online resources for students to use during their research. Included in the resources was a page with Quick Response (QR) codes that directed students to YouTube videos for each individual element. Ms. Tyson demonstrated using an iPad Scan app to scan a QR code before the students began working. As they began the activity it was apparent that some students were more comfortable than other students using QR codes to locate information. Kevin showed excitement as he and his partner began researching, “It’s like kryptonite!” Later in an interview, Kevin explained that he enjoyed using iPads and laptops in science class, “Just because it seems a little more interesting.” The students’ work was collected by Ms. Tyson, but not discussed further as a class.

The activities students searched online demonstrated the most frequently used scientific practice, Obtaining, Evaluating, and Communicating Information, which manifested itself in different ways for different students. In focus groups, students expressed varying strategies for searching online and critically analyzing information from websites. Other than the Schoology (2015) assignment, students were generally allowed to search without being directed to a specific website by Ms. Tyson. This freedom to explore and choose a method of online searching emphasizes student voice through choice, which implies that students were trusted to guide their own learning in the online environment. In this context, inquiry is open and involves search engines and websites that student can access for information—not what one typically views as
science inquiry, however, it is popular culture’s love affair with technologies that provide instant information. Most of the students argued that Google is the best place to start a search, but the evaluation of the website’s usefulness was a point of discrepancy. In the conversation below, students’ expressed their definition and ideas about of the usefulness of specific websites.

Robbie: [It is not useful] If you can’t edit on it.

Tyler: It’s true, but sometimes Wikipedia is better.

Robbie: It depends on what you’re looking for.

Tyler: But if you’re writing a paper then Wikipedia is not really for [that].

Kevin: I think it’s just my opinion, but you could use something [a website] that’s a little more close to our age. Just one of those that just gives basic facts.

Another group discussion of whether a site is one they want to use, in particular Google, revealed the following responses.

Latisha: I look under the website and they have information, and then the one that has the best [information is the one I want].

Callie: I don’t go to ones that are like Yahoo where anyone can say anything.

Further discussions lead to students being asked if they use Wikipedia. Their responses were curt and clear. As a group they responded that they did not use Wikipedia elaborating as follows:

Sarah Ann: It [Wikipedia] has too much information.

Callie: Sometimes on Yahoo people just put stuff or say I don’t know.
Andrew: Well, I know I just go to websites that aren’t Wikipedia and find the best answers.

Students seemed to recognize that anyone can edit information in Wikipedia and it may not be the most useful website. None of them stated that they looked for usefulness based on the credibility of site originator nor did they mention that a useful site is one well known for being accurate with its information. Following this idea, I asked Callie to explain whether she liked “kid websites” or “adult websites” to which she responded by saying, “I hate the kid websites because they just scratch the surface and don’t tell you anything.”

Because internet websites are highly visual, students were asked to explain whether having visuals offers valuable information searching on line (e.g. pictures and diagrams). Tyler explained, “I like websites with pictures because you can usually get facts from the pictures. There may be writing, but if you look at the pictures, you can sort of tell what it’s doing.” In contrast, other students shared different views.

Latisha: No, they don’t give much information.

Callie: Well they help me understand.

Sarah Ann: Sometimes I like it. Sometimes they’re just so unnecessary.

It seems the fifth graders held opinionated and discerning views about visuals exhibiting a wide range of ideas. Their views were often independent of the context they were considering when they responded. By not being explicitly instructed to use specific websites, student voice emerged through choice as students were given the ability to explore and utilize websites that appealed to their individual needs and preferences.
Will it float?—Investigating, questioning, and gaining confidence. As a part of the unit on atoms and particles, Ms. Tyson’s class participated in a teacher-led demonstration titled, “Will it Float?” The lesson materials were located on the back counter in the classroom—a container filled with water and a variety of small items (e.g. lemon, orange, lime, Diet Coke can, Coca-Cola can, penny, small plastic tile, golf ball, “squooshy ball”). On a handout, students recorded the item, guessed whether it would sink or float when placed in the water, and then recorded what actually happened.

Ms. Tyson began adding different items to the water, encouraging students to use the word “buoyant” to describe how certain items floated while others sank. She asked students to compare an orange, lime, and lemon that exhibited different buoyancies. After removing the fruit, Ms. Tyson then added the Diet Coke and Coke to the tub of water. The Diet Coke floated while the Coca-Cola Classic fell to the bottom causing the students to gasp in amazement. Ms. Tyson asked the class to explain why one was floating and one was sinking, even though they have the same volume. The students shared several ideas, while Ms. Tyson wrote the formula for density on the board. “They have the same volume so what has to be different? How can we manipulate the masses so that one has a greater density and one has a smaller density?” Using random numbers, Ms. Tyson demonstrated how changing the mass affected the density (Scientific Practice: Using Mathematics and Computational Thinking).

At this point, the students were engaged and excited as Ms. Tyson continued to test items in the tub of water. Most students raised their hands to indicate that they believed the tennis ball would float, and it did. The next item, a small plastic square tile caused the same type of discussion. She placed it in the water and it floated. Immediately, a student asked her to change the way she placed it in the water. Ms. Tyson obliged, causing the tile to sink! She asked the
students to explain how this happened. Kevin shared, “Because if you put it back in, there is more speed to pull it down.” Callie explained, “Because it cuts through the water.” The last item, a penny, sank each time no matter how she put it in. Students believed this happened because the penny was much denser than the plastic tile (Scientific Practice: Constructing Explanations). At this point, the lesson was put on hold to be continued the next day.

To begin the lesson the next day, Ms. Tyson asked, “Why do most lemons float and most limes sink?” Students shared ideas such as, “Because it has more armor,” and “There is more air in the lemon.” According to Ms. Tyson, “This has baffled scientists. The theory is that a lime’s skin is thinner and has less places for air to get in, so a lime has less air pockets in it.” Kevin seemed interested as he raised his hand, “If you peel the lemon will it sink?” He smiled as she agreed to test his question (Scientific Practices: Asking Questions & Carrying Out Investigations). She peeled the lemon and it still floated. When I asked Kevin in an interview how he felt when he asked about peeling the lemon and Ms. Tyson actually did it, he replied, “It feels good that I did something right ‘cause I don’t feel I do stuff right all the time.” The simple act of acting upon his question had a positive effect on his confidence. The directed-inquiry activity provided a platform for Kevin to give voice to his thoughts and ask an investigative question, which was explored by Ms. Tyson as she peeled and re-tested the lemon. In this circumstance, Kevin was empowered through the simple act of validating the power of his question through action.

**Toothpick bridges—Collaboration and empowerment in engineering.** I observed Ms. Tyson’s class during their math block as they began a month-long Toothpick Bridge project of engineering design. In the overview of the project, it was explained that “Each company will be responsible for managing their project budget and project schedule, while developing an
innovative design solution that is constructed with craftsmanship, and finally marketed to tell the story of what makes their work special.” Project guidelines can be found in Appendix K.

The first day of the project was quite busy as the students were assigned to their team, given a role, distributed their materials, discussed project requirements, and started planning. The bridge project utilized true collaborative learning where each student fulfilled the duties of a specific job on their team. Project roles included Project Director, Architect, Carpenter, Transportation Chief, and Accountant. Students were given the chance to rank their desired jobs, after which Ms. Tyson chose the students for the teams and assigned student roles. Before the project began, I asked Kevin which job he wanted the most and why.

I wanted to be the carpenter because I am really good at sometimes, sometimes visualizing things to see if it’s right. Like it seems it has to be really stable, so I can make sure how it is balanced with the things that are sticking out of the ground, they are stable.

I then asked which ones he did not want.

The accountant. [Ms. Tyson] explained what you have to do with the architect. I don’t want to do that because I am not good in math…I don’t think it’s hard, I’m just [pause] some things you just have to rush through and I forget.

Callie was assigned to be the architect, which she ranked highly. As we discussed the process of creating the bridge plans, she said, “My job is the architect. I draw. I drew the plans. Well, I was helped…I made the plans. The group helped me draw it because I’m not very good at drawing straight lines even with graph paper.” Callie recognized that although she was responsible for drawing the plans, she required the assistance of other group members, a key
characteristic associated with distributed systems (Gee, 2000). When asked what was the hardest part about drawing the plans would be she responded,

The hardest part about drawing the plans was making sure that everything was exactly the same and then counting [the toothpicks] right. (Scientific Practice: Using Mathematics and Computational Thinking)

Most students in the class appeared to be satisfied with their roles in the teams.

Before distributing materials Ms. Tyson explained, “This is a huge teamwork project. The teams in the past that worked well together did the best. The teams in the past that argued all the time tend to do the worst.” There were four teams in total, and each developed its own personality. Team one, the “Leaders,” consisted of what Ms. Tyson called the “leaders of the class.” The members, although varied in academic abilities, each had strong personalities. Callie was in this team. Team two, the “Excitables,” was lively and energetic. They were good friends that regularly finished each other’s sentences, and worked well together. Team 3, the “Agreeables,” was calm and diligent in their work. They delegated responsibilities evenly and never seemed to disagree. Kevin was a member of the “Agreeables” Team. Team four, the “Endurers” team worked calmly, though they encountered more design struggles than the other groups. They had to take their bridge apart and rebuild it twice.

Although each team encountered obstacles that had to be overcome, the “Leaders” struggled most with the collaborative aspect of the project. Callie admitted that the lack of positive collaboration affected their work when I asked her how the project was progressing. She said, “It’s not going pretty great. We’re still arguing and if we argue one more time we are disqualified.” Ms. Tyson, after weeks of working with the team, helping them improve their
communication and compromising skills, eventually instituted a possible consequence—

disqualification. This caused the group to become more civil and democratic at least on the
surface. However, Callie tended to blame one student for their overall struggles, “I hate to point
fingers,” she said, “but it’s mainly one person in the group who’s always arguing with another
person.” I asked how this experience with the difficult collaboration impacted her. She stated,
“Really, you have to [pause] you kind of have to ignore them most of the time. But the other
times you have to listen to them and not look like you want to throttle them.”

The Agreeables team, on the other hand, worked well together. Kevin explained, “Our
group is really good. We don’t argue like the other groups. We’ve gotten a lot of stuff done from
where we were. We were really behind.” Their team decided to delegate responsibilities, even
beyond the assigned roles. Kevin said,

So it’s just me [and the other two boys] working on the building. Then [the two girls],
they’re working on the poster. But Erin is the project manager so she wants to add
designs to the bridge and stuff for creativity. But another group has already done all that
stuff so I am saying we don’t want to copy them so they don’t get mad at us. Plus we
wouldn’t win the creativity award if it’s like someone else’s.

Kevin explained that he believed separating responsibility was an effective way to do things
because “If we just had one group, we’re going to want to add and then we’re going to start
arguing about something we don’t want to do.” This situation actually occurred in the Leader
team when one student complained he wanted to help build, but his teammates would not let
him. Ms. Tyson responded by saying to the team:
You are a team. No one is in charge. Everyone should be building. Everyone should be helping. One person doesn’t need to ask another person for permission, you should talk to the whole group. One person can’t give permission, the whole group gives permission.

Although the Agreeables team seemed to avoid this type of argument, I was interested in how they decided who would do what, given that the boys were building and the girls drawing. I asked if the selection with boys building and girls drawing was done on purpose which may have resulted from gender stereotypes (Anderson, 2012; Banjong, 2014). Kevin explained it was not on purpose, but “[the girls] are very good at drawing. They’re the ones that decorated our toothpicks.” He believed that they separated job roles based on strengths of the individuals. He did not recognize the stereotypical gender bias on role selection or his explanation.

Several days into the project as I walked around to observe student conversations more closely, Asia and Sybil stopped me to ask a question. The conversation went as follows:

Asia: Is this science?

Interviewer: What do you think?

Asia: No. I think it’s math.

Sybil: I think it’s science because it’s like engineering. It’s just using math.

I asked Callie if she thought the bridge building was science or math. She responded:

I think it is a little bit of both because you have to show in centimeters how long the toothpick is. It goes along with our measurement unit and I also think it is science and social studies mainly because you’re learning how to build a bridge out of short supplies.
Several weeks into the project, before a television crew came to visit, Ms. Tyson gathered the class to discuss the purpose of the bridge project. The students gave examples of things they were learning during the process that included: a) how to make a budget; b) how to work with other people; and c) what kind of things make a sturdy bridge. When I asked Kevin what he learned from the project, he anticipated that it would help him in the future. He said, “It can help you get a feel for what your employment might be for your future and how to get along with people that you don’t like.” Kevin and I discussed the Toothpick Bridge Project often and he always seemed more confident and vocal. He was proud of his bridge and his team.

When Callie and I discussed the Toothpick Bridge Project, she defined essential feature of the multiliteracies “portfolio person” and the influence of these practices on ownership of learning, including the ability to learn from mistakes and participate in decision-making (Gee, 2000). For example, she became quite passionate about having choice as a student. She went into great detail about the usefulness of this type of project, where students are given choice and freedom. She began by explaining that, “This way you learn on your own so it kind of sticks more.” She continued:

Like if the teachers tell you don’t make this mistake and you don’t make it you never really learn anything. You just didn’t make a mistake. But when you make the mistake and you fix it, then you know what to do when that happens and then how to start over.

She believed that freedom in choice of how one learns was empowering, “We’re creating it as a group. Like, the teacher can’t tell you to make it like this design because it’s your design.” When I asked if she believed it was difficult for teachers to give students this type of freedom, she responded by saying, “To me, if they’re good teachers, then no. But sometimes, you know, it
could be because you don’t know if your class is going to get out of control.” Although she
seemed to sympathize with teachers on this point, she did not believe it was an excuse to
maintain control all the time. For instance she stated,

Some teachers are just like, “We’re going to do it the old way. We’re going to keep it this
way.” But in reality, everyone, your class is different than your last class and the one
before that. So you really have to try different techniques.

Still, she emphasized the importance of having choices as a student in the following:

I think choices are very important just because next in life you’re going to have to make a
lot of choices, too. So you want to already have experience. But I also think you have a
little less control sometimes, because in the future you also have that. Like your boss
might give you fewer choices than you would have liked.

Throughout the project, students enjoyed visits from a local architect whose firm
sponsored the project. The firm provided materials to the entire fifth grade, as all of the classes
participated, and they also provided prize money. The team with the strongest bridge, as
measured by the weight it would support, was given $200 toward their charity of choice. The
most creative group was given $100 for their charity. On evaluation day, the entire fifth grade
gathered outside to test their bridges. Interns from the architecture firm assisted each class
through the process. Students clapped and cheered as more and more weight was added to each
bridge. Weight was added to each bridge until it collapsed. Afterward, students gathered around
the bridges and compared and contrasted the strongest and weakest designs (Scientific Practice:
Analyzing and Interpreting Data). For example, Luis said, “The ones with string were the
strongest because it held the sides up longer!” Although none of the bridges in Ms. Tyson’s class
won, they were thoroughly excited during the entire evaluation process, even as they watched other classes take the prize.

The Toothpick Bridge Project, focused heavily on engineering, resulting in a variety of implemented scientific practices and multiliteracies including real-world application, research, problem-solving, and collaboration. Admittedly, the project lasted several weeks compared to the other activities which may have only lasted several days. The project was also completed during the students’ math block of the day while science lessons were taught as usual in the afternoon. However, the variety of challenges and scientific and engineering practices students encountered led to a rich learning experience of not only science and engineering content and practices, including problem solving and collaborative skills.

Seen in the data, Ms. Tyson’s class’ science activities represented a variety of instructional strategies. Multiliteracies were employed as part of the instructional strategies through the use of technology devices and their applications (Science Court [Scholastic, 2015] and Researching Online), visual literacy exercises within the science text, in multimedia sources, and creating visuals in the Toothpick Bridge Project (Reading in Science, Researching Online, Toothpick Bridges), as well as real-world applications of science content (Toothpick Bridges). In addition, students enacted all of the scientific practices outlined by the NGSS. Together, scientific practices and multiliteracies engaged students and fostered collaboration and conversations that are imperative in the development of scientific literacy. Many of the same literacies were present in Ms. Randall’s classroom, though enacted in different ways, as will be described in the second half of this chapter.
Ms. Randall’s Science Class

In the previous section, I shared findings from Ms. Tyson’s fifth grade classroom. Next, you will meet Ms. Randall’s fourth grade class with a preliminary discussion of Ms. Randall’s teaching style and perceptions of teaching and learning. Similar to Ms. Tyson’s case, this discussion addresses the teacher portion of the research question, “How do teachers and students perceive multiliteracies, student voice, and scientific practices?” Ms. Randall also teaches at Littleton Elementary of Morning City Schools. She received her undergraduate degree from the same large in-state university as Ms. Tyson, although she completed her student teaching experience in New Zealand. She was in her eighth year of teaching, all in fourth grade, including one year of teaching in England as part of a Fulbright teacher exchange program. While teaching at Littleton, she also completed a master’s degree at a local teaching college.

Teaching Style: Quiet Teacher—Loud Students

As I entered Ms. Randall’s classroom, I observed empty student desks arranged in groups of varying sizes (3-5 desks per group). I often entered the class each day during their read-aloud time before science which was the last subject taught during the day. During read-aloud time some students sat on the floor or snuggled in blankets, while Ms. Randall read aloud from a rocking chair in the corner. She read very quietly, almost in a whisper, as she did during most lessons, including science. Although the classroom climate during science was frequently active and noisy, when she spoke, she spoke quietly and the students listened. During science, students moved freely around the room to get supplies and talk with their peers while working on independent or group tasks. She confessed, “It’s not as quiet as I’d like for it to be, but I don’t
like silent classrooms.” Although she personally preferred quiet time, she believed that classrooms were not meant to be quiet spaces.

Ms. Randall’s description of her own prior science experiences could be described as lackluster. She reflected,

Science was not my favorite subject when I was younger. Even though I loved my teacher, he was not my favorite teacher. He was kind of old school. We did a lot of worksheets. We did dissections but I don’t remember doing anything else hands on besides dissection. So I didn’t really like science because it was a lot of note-taking or watching boring videos or something. So I’m trying to remember science teachers that I really did like. That sounds really bad. … I didn’t hate my teacher or anything, but yeah I didn’t love it. Even in high school and I guess in high school more I did enjoy biology but I wasn’t great at it, possibly because I didn’t have a good foundation. So it wasn’t as much fun because it was difficult for me. But chemistry, I hated.

As she recalled her personal experiences, she attributed her current teaching style to the desire to offer different, more interactive experiences for her students:

I guess thinking back to my science experiences that weren’t totally positive…I try to make [science] interactive and as hands-on as possible. We haven’t really gotten the textbook out at all this year.

In the time I spent observing science in Ms. Randall’s classroom, they indeed did not use the science textbook at all. They did, however, read text in the form of comic strips, picture books, websites, and PowerPoint presentations. Despite not using a science textbook, Ms. Randall acknowledged that her students sometimes struggle with the rigor of inquiry-based activities,
implying that the students may not appreciate the benefits of problem-solving in comparison to being passive receivers of content knowledge. Students often are resistant to inquiry because of the expectations they have had of being told what they need to know:

> I feel like they learn so much better if they research it and find it out rather than me telling them, but I’m not sure they get that. Or they’re just lazy. I’m not really sure but sometimes they just want me to tell them.

In order to effectively implement inquiry practices in the classroom, teachers require a strong background in both content and pedagogy (Capps, Crawford, & Constas, 2012). Ms. Randall expressed comfort in the ability to more easily implement investigative, inquiry-based activities through the use of a kit-based science program.

When preparing science lessons, Ms. Randall explained that the fourth grade team does not plan together on a regular basis, though, they did complete several large grade level projects throughout the year including a Living History Museum. With respect to science, Ms. Randall utilized kits from the Alabama Math, Science, and Technology Initiative (AMSTI) program which incorporates collaborative experiences (2013). She used AMSTI (2013) activities frequently throughout the year. AMSTI (2013) teachers receive several science “kits” throughout the year that include student supplies and instructional materials. In order for teachers to receive the AMSTI (2013) kits for their grade level, they must complete the required training. This training and the availability of the kits may be one reason she does not see a need for reliance on a textbook.

Ms. Randall described a typical science lesson in her class as some variation of an AMSTI lesson (2013), “Really most of the lessons are probably AMSTI based, so more are
hands-on than they used to be. Sometimes there will be some reading involved.” Although the AMSTI kits (2013) were a staple and prominent resource for many of her lessons and units, Ms. Randall pointed out her tendency to alter or adjust the premade lessons. For example, I inquired about AMSTI’s (2013) ability to address the standards of her grade level and she responded with a critical review of the kits, “That is part of the problem. Those units take so long to teach that the other standards that aren’t covered sort of get thrown to the wayside. So I have a hard time with that.” She felt accountable to adequately address all of the standards assigned to her grade level and adjusts her teaching, curriculum and materials as needed to do so as seen in the following:

We do the animals kit which I really sort of despise. The kids love having the animals, but pretty much the entire book is about observing the animals. The course of study is like, life cycles of animals. We get frogs, but we don’t get them as tadpoles so how does that teach life cycle? A couple of years I have actually not ordered the animals and I’ve ordered my own. I got ladybugs and caterpillars. We’re supposed to teach the food chain, invertebrates, vertebrates, and classification. Just observing them doesn’t really do that.

Ms. Randall’s knowledge of the state standards for her grade level provided her with the confidence and justification for modifying the state-advocated AMSTI kits (2013). Realizing that the kits did not address what was needed or important for the learners in her class, she altered the kits by using alternate resources as lessons.

Though she used AMSTI (2013) materials for science activity, picking and choosing what she wanted her students to do, she also integrated other resources including the internet where she simply tried out “other things.” She said,
I definitely deviate from the AMSTI book, but fairly follow it. It’s more like I skip lessons or add in some things. And a lot of that may have actually come from my training where I got ideas from other teachers or whoever was teaching us.

Ms. Randall also reported that the AMSTI kits (2013) and professional development contributed to her comfort with the science content taught in her class.

**Students as “Questioners” and “Wonderers”**

Ms. Randall voiced that in order for her students to be successful in the future they needed communication skills and problem solving skills, both of which reflect aspects of multiliteracies. In the following, she explains that she utilizes lessons where students are required to problem solve:

In math I feel like we do a lot of problem solving and in science I feel like we’re doing more problem solving. And I really like doing more of those where I sort of present the problem and they have to figure it out. I would love for there to be more time. [In a] picture perfect world [there] would be this big project based learning where we ask a big question, or where they are asking the questions. Communication, I feel like we do a fair amount, making sure that hopefully we’re listening to each other and sharing. We do a lot of sharing in math as well, so I hope that means they can talk about things other than math and science.

Her goals describe her approaches to teaching math and science. Furthermore, the description is a form of inquiry-based teaching that fosters learning where students are engaged in solving problems and investigating different phenomena (NRC, 2000). Ms. Randall’s emphasis on problem solving with students was also expressed in her expectations for student performance in
science. When asked what she wants her students to be able to do in science by the end of the year, Ms. Randall responded, “I really hope overall they can go through an experiment. They can question. They can predict. They can make observations and draw conclusions based on that.” These processes, questioning, predicting, observing, and drawing conclusions, are fundamental practices in the progression of scientific and engineering practices of the NGSS (NGSS Lead States, 2013c). Ms. Randall’s experiences in teaching science through problem solving has made it clear to her that students struggle the most with predicting and drawing conclusions. For instance she said of drawing conclusions, “That’s using things (evidences) to bring it together. It’s putting pieces together to bring it back.”

Ms. Randall aligns inquiry with her views that students should first ask questions and second seek answers. For example, she stated:

I want them to also be the questioner and the wonderer. I still think, this group is (pause) I’m not going to say they’re fairly bright and I won’t say they’re not bright. But they’re fairly accustomed for things to come easily and not having to think. So I find myself pushing them more because I want them to be the ones who are asking the questions and also finding the answers. They do ask a lot of questions, but then if I can’t answer it, oh well!

The notion of students as questioners and wonderers is recurring in Ms. Randall’s interviews. Observation data reveal that she acted upon this view whereby questioning and seeking answers was encouraged. She allowed students to question, wonder, and search for answers while frequently incorporating the use of multiliteracies by including collaborative exercises utilizing technology. As mentioned, Ms. Randall’s science goals for her students along with her actions to
assist them in attaining them, creates a need to form links to resources and activities associated with answering their questions. This can open many avenues for multiliteracies. As such the next section provides insights into Ms. Randall’s perceptions of multiliteracies.

**Perceptions About Multiliteracies: “I Just Haven’t Completely Figured it Out.”**

In planning lessons that were relevant to students and in line with required academic standards, Ms. Randall implemented a variety of tools in her classroom. Students interacted with not only each other, but also with challenging activities and technology in multiple ways throughout independent activities and units. Multiliteracies were evident in students’ use of technology, visual literacy, and the development of collaborative skills.

**Technology.** Ms. Randall’s classroom was equipped with an overhead digital presenter, several laptops, four iPads and a grade level laptop cart. The students in her class also took advantage of the Bring Your Own Device policy, of which Ms. Randall was appreciative, for the more mobile devices available in class, the quicker and more efficient the process:

I am enjoying [students bringing in their own devices], and it’s gone a lot better than I thought it would. It’s been really nice when I just want them to look something up in their groups and we don’t have to give out laptops and wait for them to load.

Having multiple devices in the classroom, including ones brought to school by the students, enabled them to quickly search for answers to questions, a process valued by Ms. Randall. The use of mobile devices, compared to laptops, allowed the process to occur quickly and with ease.

One platform frequently used in Ms. Randall’s classroom was Schoology (2015), an online learning environment or “Facebook with your teacher” as one student described. The use
of the internet and mobile devices for school assignments at home was an area in which Ms. Randall felt tension. When asked about homework assignments on Schoology (2015), which were frequently assigned in her class, Ms. Randall admitted to struggling with assigning activities for homework that require technology because of the unequal access to technology. She stated,

I’m working on that. Everyone’s parent has a smart phone, so technically they should be able to do it at home. Alicia doesn’t have a computer, but she also only turns in her homework half of the time. So I can’t tell if she’s not doing it, or if she actually doesn’t have [access]. I’ve talked to her, “You know you and your mom can go to the library.” And they always have a week to do it. I mean, her mom has an iPhone. I do Schoology on an iPhone, so it can be done.

In her statement, it appears that Ms. Randall was trying to convince herself that although access to technology is not equal for the students in her classroom, students should be able to access the internet for assignments in some fashion. She mentioned access again when describing her use of online applications:

For research stuff, I loved when we did technology in space, I loved that they were able to do some research. That was really our first experiment with Google Drive (2015) and that went really well. I don’t use it enough, but I have such a hard time because I know they use it at home. But I also know that not everyone’s technology at home is equal, so I have a hard time having them do things at home.
Technology as a key component of multiliteracies presents a unique dilemma for teachers, as Ms. Randall points out with respect to the students’ unequal access and ability to use technology outside of school.

Ms. Randall was very aware of the evolving and innovative nature of technology and its influence on the classroom:

I can’t imagine how much science is going to change in the classroom in five years. With the devices, that has changed so much this year. When I left, I only had one when I left. So now having four and having students bring their own devices has been really different. Thinking that there will be more things kind of like web quests when everyone has their own devices. I will be excited about that.

However, when asked about what her classroom would be like if each student had a device, she was candid in her response. She was both excited about the possibility while also aware of the notion that it will require adaptations to her current teaching practices:

It makes me kind of nervous. I have to wrap my head around how I want to manage that. You enter into a whole new world when you can bring your device in. The Google Drive, I have loved this year and it’s been fabulous. What I think I love is the group projects, because whenever they’re doing something…what’s great about it is that one person doesn’t have to sit at the computer with everyone standing around them. They can all be on the computer they can all be sharing information. It’s been an easy way to share things with them like photographs that I’ve taken or videos or like we’re doing something and there’s a lot of different websites I just created a document and they can just click on it.
Google Drive (2015), a cloud based platform for document creation and sharing, has worked well as a learning and communication tool, according to Ms. Randall. Students have the ability to not only create content, but communicate ideas and share information with their peers and others easily in and outside of the classroom. Using online tools such as Google Drive (2015) is a growing trend for multiliteracies development in classrooms (Denton, 2012). However, Ms. Randall noted the friction between the use of these tools and traditional classroom practices such as homework and giving grades. She says,

I haven’t given grades. I still haven’t figured out exactly how I want to use this. I really started using it after we came back from Christmas. So last week when we were out for so many days [because of snow], I wanted them to have some practice. So I made a five question division quiz. Some of them did it. Some didn’t, so I extended the due date. I could see this being really beneficial like putting it on here and having every kid bring in a laptop. But then you don’t have a printout for the parents. And I like having the paper test to be able to pull kids and talk about it. And I don’t want to assign a quiz to do at home when mom or dad could be helping. I just haven’t completely figured it out.

Ms. Randall was eager to implement technology in her class efficiently and effectively, although she admitted to still “figuring it out” when it comes to homework and testing. One of the major benefits she noted was the ease of collaboration with using online tools. Ms. Randall’s perceptions about collaboration in her classroom, including its correlation with the new Common Core Standards that address communication and collaboration are discussed in the next section.

**Student Collaboration.** As noted earlier, Ms. Randall’s class was an environment in which students conversed with each other almost constantly. However, Ms. Randall clearly
demonstrated that students need to learn that there are certain times to talk and certain times to work independently:

I do really like that [students talk to each other] and there are times during the day that I think it’s better for them, like during writing, I don’t really want them talking too much. I hope that they figure out sort of when it’s the appropriate time to talk and collaborate. There’s no reason for them to be coloring and silent, as long as they’re getting their work done.

Skills of flexibility and awareness of appropriate collaborative behavior in a learning environment is a key feature of the “portfolio person” (Gee, 2000). The development of these skills is another important component of multiliteracies needed as students are preparing to work and live in a fast capitalist society where collaboration is critical (Gee, 2000).

Ms. Randall’s classroom was a beehive as students interacted with content, each other, and a variety of digital tools and other resources. As she stated, she was willing and eager to encourage this collaboration and development of multiliteracies, although she was still grappling with issues of effectiveness and logistics. As students became more actively involved in collaborative work in their classroom learning community, student voices appear as they begin to take ownership of their knowledge. Ms. Randall emphasized the importance of student ownership in their learning as she discussed her perceptions of student voice.

**Perceptions About Student Voices**

Ms. Randall’s perceptions of student voice emerged or even evolved over the course of many conversations. For example, when discussing typical science lessons in her class, she connected the use of interactive learning with student ownership of learning. She notes,
[I use] hands-on, interactive projects, anything that will hopefully give students more ownership of their learning or the project. I think they enjoy it because of that. I try to [pause] I would love if I could have them ask the leading questions more, but sometimes it [gets off track]. Sometimes it doesn’t hit what we’re supposed to be studying. I would love to have that opportunity more.

In this instance, student voice was defined as students’ ability to guide their own learning through questioning. Ms. Randall, however, revealed that allowing students to investigate questions not directly tied to the topic of study are sometimes overlooked because of her responsibility to teach a specific set of standards:

As far as what they’re interested in, that’s the really hard part for me because I would love to have more time to just do what they’re interested in, but I have to make sure that I also get what’s in the course of study taught, so a lot of times if there is something that we’ve talked about that they’re really interested in I will encourage a kid to look it up and share information with us the next day or I will find some basic facts that answer those questions and share that.

Here, she acknowledged that students’ interests are sometimes peaked, but instead of exploring those interests in class like she would prefer, she asks that students explore them at home and then share the information the class. She was aware of maintaining the integrity of the required course of study.

Similar to my discussions with Ms. Tyson, I also addressed student voice in conjunction with The Whole Child because of the school’s familiarity with that term. Ms. Randall’s
responses indicate an awareness of student diversity, resulting in a desire to use varying teaching strategies to connect to each student. For instance, she noted,

Part of it [The Whole Child] is teaching in a variety of ways so you get those kinesthetic, those auditory and visual learners. Part of it is that. But I also think part of it is creating lifelong learners and creating citizens. Things like that, so you’re not just teaching them math and science. I guess for me in my classroom, trying to connect those things to the real-world affecting the children. What’s going on around them? What might be important to them? [I would like to find] things that they find interesting or trying to teach a variety of subjects in a variety of ways so that you teach all of the kids at least at some point. My hope is that in all the variety, I reach all of the kids in one way or another. That each kid has a voice.

Ms. Randall’s perception of teaching the whole child incorporated several components. First, she identified teaching the whole child with various learning styles and learning needs. She also noted maintaining relevance and engagement with the goal of creating “lifelong learners” and “citizens.” Her perceptions of teaching the whole child, creating knowledgeable, problem-solving citizens, is a fundamental component of science literacy (NRC, 1996).

Ms. Randall also noted the relationship between student voice and enjoyment of learning when she stated that, “I really hope that with the variety of stuff that each kid finds something that they enjoy, something they’re proud of, something that grabs their attention, something that keeps their interest.” However, when addressing voice on a broader, more organizational level, Ms. Randall was more hesitant. When asked if she believed students should have a voice in the workings of their school, she had concerns:
I do. This age [pause] sometimes it is hard. I feel like they might be a little young for that. They’ve got some good ideas but it takes some channeling and you don’t want to put ideas in their head when you’re channeling.

Ms. Randall was willing, although hesitant, to support student involvement in school matters. She noted that young students in such circumstances would require quite a bit of guidance which may defeat the purpose of their involvement.

Ms. Randall’s perceptions of multiliteracies and student voice were evident in her desire to provide meaningful and interactive science in her classroom. She acknowledged the evolving nature of science teaching with technology in the classroom admitting to not knowing how she will adapt in the future, though willing to do so. In the next section, multiliteracies and student voice are addressed within the context of events and curriculum in Ms. Randall’s classroom.

**Classroom Experiences: From Both Sides**

This section begins with a brief look at Gabriella and Aaron, the two students purposefully selected from Ms. Randall’s class for individual interviews. The student descriptions are followed by an exploration of the students’ perceptions about two cloud-based technologies used in Ms. Randall’s classroom, Google Drive (2015) and Schoology (2015). Following discussion of the technologies, are descriptions of classroom activities/units in Ms. Randall’s class. The first activity, Make it Light, is part of the AMSTI (2013) electricity unit. The other activities were part of the redesigned animal unit which Ms. Randall used as a replacement for the AMSTI (2013) kit she felt did not adequately address the standards for her grade level. Discussion of the classroom activities focus particularly on multiliteracies, student voice, and scientific practices as the following research questions are addressed:
1. What and how are multiliteracies, science, and scientific practices implemented in the elementary science classroom;

2. With respect to learning science and scientific practices in the classrooms of study, how are student voices engaged through multiliteracies?

3. How do teachers and students perceive multiliteracies, student voice, science, and scientific practices as they are enacted in the classroom?

As such, multiliteracies in the forms of visual literacy, student collaboration, problem solving, and interactions with a variety of technological tools are identified. Throughout the discussion, scientific practices are identified for later discussion.

**Gabriella.** Gabriella, a fourth grade student in Ms. Randall’s class, was described by her teacher as a “perfectly average” student. When she grows up, Gabriella would like to be a photographer, clothing designer, or horseback rider. She was very energetic and liked by her classmates. She asked a lot of questions when she did not understand a topic or assignment in science and appeared eager to listen and learn. She had a sense of humor, laughed a lot, and frequently shared jokes with her classmates. She was often humorous, even in our interviews. For example, the following is a casual exchange we shared about the enjoyment of learning and grades where she laughed as she could not believe that I enjoyed math as a subject:

Gabriella: I hate math.

Interviewer: Why?

Gabriella: Because it’s math. [laugh]

Interviewer: That doesn’t make sense to me.
Gabriella: Yes, it does! [laugh]


Gabriella: You do?

Interviewer: Yes. I think it’s cool.

Gabriella: I kind of like math. It’s definitely not my favorite.

Interviewer: Yeah? What about it?

Gabriella: Some things are hard.

Interviewer: I don’t understand why you don’t like it.

Gabriella: It’s MATH! [laugh]

**Aaron.** Aaron was also a fourth grade male in Ms. Randall’s class. He has been tested for the gifted class, but was not accepted into the program. When he grows up he would like to be a lawyer or professional soccer player. During an informal conversation, he and I were pondering Brazil’s chances of winning the World Cup. He was very conversational and shared with me how to say “hello” in Portuguese. He was eager to share information, “I know people in Brazil speak Portuguese because I’m Portuguese. … I can say hi. …I know they eat fish and stuff.” Like his classmate Gabriella, Aaron asked a lot of questions and was eager to participate in class. He was friendly to others and frequently laughed and smiled during classroom activities.

**The Cloud.** This section explores the role of two cloud-based programs, Schoology (2015) and Google Drive, in Ms. Randall’s class.
**Schoology.** Schoology (2015) is an online “learning management system” with a wide variety of uses including course management, mobile learning, and communication. Sasha described Schoology (2015) as an “online place where [Ms. Randall] puts up assignments. We do the assignments and then we comment.” Jessie added that it is “like Facebook.” The assignments they refer to were typically done as homework, which Keon said, “was a lot better than having a sheet and having to read.” Other students contributed to the conversation on Schoology (2015) in the following:

Jessie: It’s kind of like Facebook for school, but they assign assignments.

Destiny: It’s Facebook with your teacher.

The structure of the assignment varied from science videos with questions to reading assignments and quizzes. Destiny explained, “She posts stuff that we have to read. We have to read it and then take a quiz on it and tell her what we did.” In some assignments, students were given the tool ability to comment in a classroom thread, giving them voice in another environment—the online environment. Students said,

Destiny: You can read it and like it and people comment. You can comment like…

Jessie: You can say like I disagree. You can say like, that was a good idea, but I think it [something else].

Destiny: They say ‘like,’ or ‘Good job that’s really awesome!’ I’m like, oh thanks.

Jessie: Alex almost always disagrees.

In another focus group session, Alex remarked that the comments on Schoology (2015) were useful when they may not understand the homework concepts:
And we can interact with other students. Like sometimes she says comment down and we’ll talk about what we did and then they’ll comment down. Like if I didn’t understand something, someone in the class understood it.

Alex referenced Schoology (2015) as a tool in which she can assess her own understanding of a topic compared to the other students in the class. Students are able to assist each other in this environment through online communication. This collaborative environment, again, is conducive for developing multiliteracies, specifically communication and learning community support skills. In this instance, the collaboration takes place in an online environment, requiring student interaction with not only other students, but technology as well.

**Google Drive.** Google Drive (2015) is a cloud-based file sharing and storing platform. Students are able to work on the same file from different devices at the same time, access files from different locations, and receive feedback and information from Ms. Randall. The students of Ms. Randall’s class voiced that Google Drive (2015) was not only enjoyable, but more efficient than storing files on a hard drive.

  Alex: I like Google Drive because it’s fun.

  Chloe: It is really fun, and it’s just so much easier.

  Tish: It saves automatically.

  Alex: We can all be in different places working on it.

  Chloe: And you don’t have to like write everything on a piece of paper.

  Tish: It has a research little box on it, so you don’t have to leave the tab.
Tish continued, “On PowerPoint it was really hard to save because you had to go through all of this and you could click on the wrong file and you could go through all of it, but [Google Drive] saves.” Chloe noted that she was able to work on school assignments at home through Google Drive:

I just, what was it called, I did a URL. Last night I was working on my project a little bit because I just got a whole bunch of notes yesterday so I had to change everything about my project last night.

Chloe identified a useful feature of online environments in that they are accessible not only from school, but from anywhere. Tools such as Google Drive (2015) and Schoology (2015) have created a collaborative environment that moves beyond the classroom walls. Students were able to communicate from any device in any location working individually or with others within a virtual collaborative community. In the next activity, students engage in scientific practices as part of an AMSTI (2013) unit that activates an alternative set of multiliteracies through an investigative activity.

**Make it light: Investigating, struggling, and succeeding.** This AMSTI Electric Circuits kit (2013) began with a lesson devoted to exploring students’ prior knowledge of electricity, as well as addressing safety. Ms. Randall asked students to use small dry erase boards at their desks to write ideas they have about electricity. She prompted students with questions such as, “Think about how electricity works. What makes it work? What different things do you know about circuits or charges or currents?” Students were asked again to share their ideas, which Ms. Randall listed on the board. The following are some examples of student responses from observation field notes: “I know it powers things. It can give power to things like heaters and
lights, devices.” “It’s dangerous.” “It flows through wires.” Next, students were asked to write questions they had about electricity on their white boards (Scientific Practice: Asking Questions). Again, students shared their questions with the class as Ms. Randall wrote them on the board. Questions included, “What is a circuit and what is an insulator?” “What are magnetic fields and what do they have to do with electricity?” “Can you feel electricity with your body and how can you make electricity?” and “How can you conserve energy?”

The exploratory part of the lesson was entitled, “Make it Light.” Ms. Randall posted the lesson’s learning targets on the projector, as she did each day: “I can use electricity to make a light bulb light. I can use the scientific method.” Students were then asked to write “Light Bulb” and the date at the top of their page, and then to copy the following from the projector:

Question: How can I make a light bulb light?

Hypothesis: ___________________________

Materials: Battery, light bulb, wire

One student immediately asked, “Is our hypothesis what we think is going to happen?” Ms. Randall answered by saying, “Your hypothesis is how you think you can get the light bulb to light.” As students wrote, Ms. Randall distributed an AMSTI (2013) box of materials to each student (about half the size of a shoe box). The class then shared their hypotheses aloud. As students observed the materials in front of them, one girl whispered to herself, “This is going to be hard.” The class then shared hypotheses aloud. Examples included, “I think the light bulb will light up by connecting the battery to the wire and light bulb so the energy will go through” and “I guess connect them, the wire, the battery and the light bulb.” Then, Ms. Randall shared the day’s challenge:
The challenge for today is for you to make the light bulb work. The hard part is that once you figure it out, I don’t want you to show anyone how you did it. Once you figure it out you can raise your hand and I’ll come look, but I want everyone to have the fun experience of discovery. Are you ready for your challenge? Good luck!

Directions were listed on the PowerPoint:

Observation: Draw an illustration of how you made the light bulb light. Write about how you figured it out, if it was easy or difficult.

Conclusion: How did you make the light bulb light?

Next Step/New Questions:

Students immediately began working with the materials to light the bulb (Scientific Practice: Developing and Using Models, Planning and Carrying Out Investigations). Although some students made comments that hinted toward frustration, they also seemed excited. Some students made encouraging comments to themselves and others such as, “Believe in yourself, for once!” and “Don’t give up, you’re going to be a scientist!” Eventually, students one-by-one began to figure it out. One student jumped out of his seat and yelled, “I got it! I got it!” Others grew increasingly frustrated, “I know, but I can’t get it.”

Throughout this process, Ms. Randall walked around the room taking pictures of each student and their lit bulb which were eventually posted to her blog, a way in which she shares information with parents. As the science period came to an end, she explained that if a student had not figured it out yet, they could ask a friend for help.
In a group of students, one girl, Sasha, lit her bulb first and then shared with her group, "It's so easy once you figure it out!" The other girl at the table, Destiny, responded by saying, "It's not easy to me. Stop rubbing it in." Eventually one of the boys at the table, Jessie, lit his bulb as well. He immediately began helping the other boy at the table, Keon, by giving clues but not showing him directly where to place the materials. In a focus group with the students, I asked why and how they helped each other during the activity, even though it was intended to be an independent activity.

Sasha: Well somebody was like…sort of like hinting.

Jessie: I gave Keon some hints.

Keon: Jessie gave a bad hint.

Jessie: Well I didn’t want to give it away. It’s hard not to give it away.

Jessie, knowing that one of the goals of the activity was to discover the solution independently, took on the role of a teacher through questioning and “giving hints” while not explicitly sharing the answer. Students frequently collaborated in ways such as this, so it was not surprising that such communication took place during this particular science activity.

Destiny, although admitting that the activity was “fun,” also suggested that seeing others accomplish the goal first was frustrating, “I thought it was supposed to be fun, and then I finally got it when she told us to stop.” I continued by asking if the process of trying was as fun as obtaining the result. She responded by saying, “Well everyone else was getting it. It was fun, but some people were trying to get it. And some people were like, ‘Oh I got it already.’” As part of their science notebook assignment, students were asked to explain if they thought the activity
was difficult or easy. This prompt encouraged a moment of reflection for Destiny that we discussed in our focus group. She admitted, “I get really mad at myself when I can’t do something.” She also recognized the joy in overcoming such an obstacle, “We got mad when we couldn’t do it. We were really happy when we did get it.” The other students agreed:

        Jessie: I thought it was kind of hard.

        Sasha: When I got done with it, it was easy. When I first started I was like, Oh gosh how do I do that? […] It was like a good hard. You know that you can do it, but it’s really hard. Then you get it and it’s fun.

In a later conversation, Ms. Randall recalled these events and explained that it was a wonderful and empowering experience for both girls because Sasha tends to struggle academically whereas things come quite quickly to Destiny. Reflecting upon the activity, Ms. Randall believed that the process provided a needed struggle for Destiny as she had recently displayed poor sportsmanship during their class spelling bee:

        Yeah, I loved how quickly it became impossible. I loved how [Destiny] had such a hard time. I think I called that one when we were talking about it last week. She is going to get frustrated if she doesn’t get it first.

Again, Ms. Randall was able to acknowledge student strengths and weaknesses in relation to the activities and skills being incorporated in class.

        When asked what they believed their teacher learned about them from the electricity lesson, the students provided a variety of answers:

        Keon: That we persevere.
Destiny: That we can write.

Keon: I know why she would give us hard stuff—to see how we react.

In an interview, Aaron described the electricity activity as his favorite activity in science for the entire year. He said, “I thought it would be really hard to make a light bulb work, but it was actually really easy. All you need is a wire, a battery, and a light bulb.” He suggests looking back on the activity that learning by doing was easy for him and may be linked to enjoying it. In science, it was important to make things, he said, “So you can know how it works and stuff. If we just talked about it, I don’t think it would be fun.” For Aaron, hands-on activities appear to strengthen his visualization of concepts more than talking about it.

One focus group of students admitted that hands-on activities such as the Make it Light lesson are their preferred way to learn as seen in the following:

River: I like to learn with my hands.

Asia: That’s what I was going to say.

Sam: It’s fun to make stuff without instructions like put this there. We just put things randomly. …

Asia: I’m better learning by touching things and building things.

River: That’s the best way to learn.

Sam: Me too.

Interviewer: Do you think your teachers know that about you?
Group: No.

Asia: I mean she probably knows that I do like it but she probably doesn’t know that we like to touch and feel things.

River: It matters if you have a good teacher and she studies you. … She sees how you learn. Ms. Randall does that.

Asia: She’s always looking at our work as we’re doing it. Like sometimes I’m doing math and she’s looking over my shoulder. [She says] like good job those answers are all right.

Sam: And sometimes she’s like no that’s not right.

River: Almost all of our science projects we get to do things with our hands.

River believed that having a teacher that “studies you” helps her determine the most effective practices to use in her class. Another group agreed that the “doing” of science was extremely beneficial in their learning. Comments included:

Alex: It was a long, long unit and that’s what we didn’t like at first. We liked learning how to light the light bulb but then we got into the notes. I was just bored because we know most of the stuff and it’s just like [exhausted face].

Tish: So much to write down.

Alex: Yeah we hate writing stuff down.

Chloe: I like to, I don’t really like taking notes and everything because they don’t help me. Doing projects, I don’t know if it’s just me. But actually doing stuff, like doing the
light bulb experiment, that actually helped me more than all the notes that we were forced
to take down.

Chloe remarked that the students were “forced” to take notes in addition to the light bulb
investigative activities. Although she did take notes, she did not feel that they were beneficial to
her learning. The other students agreed that they did not enjoy taking notes.

Although note-taking was a common practice in Ms. Randall’s science class, she found
hands-on learning that engages and prompts student questioning to be one of the most exciting
aspects of teaching:

I love seeing those light bulbs go off. Sometimes literally, when we do the electricity
experiment or we do the electricity unit. That’s probably my favorite. It is the very first
one when I give them a light bulb, a battery, and a wire and say, ‘Make it light.’ They
think that it’s absolutely impossible and no one can get it and they’re so frustrated. Then
that little light bulb goes off and it’s so much fun. Then you know it’s easy from then[ on]
and I love seeing those things. I do love seeing curiosity sparked and then asking
questions and wanting to see more. I don’t think they go home and search for answers as
much as I would like to see them do. But yeah, sparking curiosity and seeing those ‘AH
HA’ moments [is exciting in teaching].

The scientific practices utilized in this investigative activity, including Asking Questions,
Developing and Using Models, Carrying Out Investigations, and Communicating Information,
created a learning environment which required problem solving and perseverance (NGSS Lead
States, 2013c). The development of the multiliteracies, along with visual literacy and the
scientific practices, resulted in students feeling engaged, accomplished, frustrated, and later
empowered. Persistence through adversity and frustration, is a necessary process involved in multiliteracies as students develop the ability to problem solve and experiment with new ways of tackling not only scientific problems but societal problems, as well. In the next activity, students continued their development of visual literacy through the use of comics with a boost of independence associated with student choice.

**Cell comics.** The following is a series of lessons in which students explore the classification of living things beginning at the cellular level. To begin the unit on animals, Ms. Randall explained to the students that although cells were not part of their course of study, she believed it was important for them to be familiar with the concept before moving forward.

Students were then given the opportunity to learn about cells through a reading activity. Ms. Randall distributed comic strips to the class, which they took turns reading aloud, box-by-box. As they read, she paused to explain unfamiliar concepts and vocabulary. They continued to read, stopping after every box/picture to discuss what was read. In a focus group, students explained that reading the comic strips was “fun” because “it has drawings in it” and they “like drawings.” Aaron also enjoyed the comic strips because they are “a lot shorter.” After reading several of the comics, the students pulled out their lab notebooks to take notes on the material. Ms. Randall asked the students to write “Cells” at the top of the page to match a PowerPoint slide she was displaying on the projector. As students wrote notes, she applauded the note-taking strategies of several by saying, “I love that some of you are using bullet points. That is the best idea!” Although she had already prepared several key points on the PowerPoint slide, she encouraged students to add any other important information they felt needed to be addressed.

In pairs, the students then read the remaining comic strips and wrote three interesting things they learned about cells on their dry erase boards. Their interesting facts were shared with
the class before ending for the day. The next day, to review, students were asked to choose two to five squares of their choice from the comic strips to cut and paste into their lab notebooks. In a focus group, Tanya explained that being able to choose which ones to cut made her “feel more responsible.” In another focus group, the students also referred to the brevity and “fun” nature of the comic strips for both reading and selecting for the cut and paste: For instance,

Chloe: I think that comic strips are a little more fun because we get cute little pictures.

Alex: Yeah they’re just easier to learn because if you’re reading a book you’re like [bored face]…

Tish: Yeah the textbook has big words.

Alex: It’s ‘funner’ to like, do it.

Chloe: I thought it was more fun to interact with them. Like we did a little activity where we would choose a couple of them that were good.

Ms. Randall opened the next part of the science lesson by reviewing the comic strip squares the students chose to glue in their notebooks, “I found it really interesting which part of the comic strip you cut out and glued. Would anyone like to share which boxes you cut?” Students took turns sharing the information they thought was interesting by reading the squares in the notebooks. In this brief activity, student voices were engaged through freedom of choice. Their voices were supported and encouraged by Ms. Randall and each other through positive affirmations concerning the comic squares they believed were important and interesting. Students chimed in with, “I cut that one too!” and “Yeah, that’s a good one.” In the following
activities, students utilized the freedom of choice with electronic devices as they continued to learn about the classification of living things.

**Kingdoms: A variety of visuals.** The second activity focused on the classification of living things, beginning with an overview of Kingdoms as a classification system. Students then watched a BrainPop (2015) video, twice. The first time, Ms. Randall asked the students just to watch, but the second time they were encouraged to take notes in their foldable. When discussing information the students wrote, one student stated that she was “99% sure” that plants are multicelled. Ms. Randall suggested that if she was not “100% sure,” it was worth waiting to find out before writing it down, stressing the importance of finding evidence to support student ideas. Watching videos multiple times is a practice in using videos as a tool for finding and learning information.

After the BrainPop (2015) video, Ms. Randall indeed utilized another resource for the students to explore. She posted two websites on the projector as a reference for students to use as they researched information to complete their foldable. She explained that students could use Google to find information, but that the two identified websites would be useful places to begin. In the foldable, students not only recorded written information about each kingdom, but they illustrated each kingdom as well. This again requires visual literacy in the form of creating images and diagrams for the purpose of illustrating a concept. These particular images are an example of Moline’s (2012) picture glossary where a simple object is drawn and labeled. The students worked in pairs using a variety of devices including classroom iPads and students’ personal devices. In total, eleven devices were used. The students worked until the end of the class period and then were given an opportunity to share information with the rest of the class.
before packing up for the day (Scientific Practice: Obtaining, Evaluating, and Communicating Information).

As students worked, a surprising social situation occurred. Two Caucasian boys were working together, but were laughing and seemed a bit off task. Although I could not hear the entire conversation, it resulted in one of the boys jokingly calling the other a racist. Ms. Randall approached the two boys quietly, kneeled down next to their desks, and began a conversation about the seriousness of such an accusation. The student explained that he was joking, but Ms. Randall persisted in her notion that racism was not a joking matter under any circumstances while drawing upon the lessons they recently learned in their social studies unit on the Civil Rights Movement. She was not chastising the students, but rather using the situation as a teachable moment. The two students apologized and she left their table. This unexpected event illustrates another aspect of multiliteracies. It is the development, respect, and appreciation for our increasingly diverse, yet connected, societies (Cope & Kalantzis, 2000). By addressing these instances as they arose, Ms. Randall was teaching her students multiple ways of seeing, respecting, and developing sensitivity to diversity in its many guises.

In this activity, Ms. Randall’s primary use of several multiliteracies focused on the efficient use of videos and online resources for information gathering, analysis and evaluation of information, as well as note-taking. Visual literacy in this activity was incorporated through student illustrations of the adaptations of living organisms. Students identified a variety of tools, visual images, and choice as important features of their learning environment. Last, the conversation about race between the two boys provided a space for teaching cultural sensitivity in social interactions as a part of multiliteracies. Next, the findings reveal the use of multiliteracies and choice as a tool for engaging students as with Ms. Tyson.
Classifying animals: Science, technology, and choice. Ms. Randall’s lesson used a PowerPoint with embedded websites to present information about animal classification, both of which included text and images. She encouraged the use of bullet points as students were writing notes, and she pointed out unfamiliar text features. For example, she asked, “What does it mean when you see words in parentheses right after a word? The tiger (*Panther tigris*).” Students guessed why the parentheses were used. Then, Ms. Randall explained, “I thought it might be the tiger’s classification. I wanted to know if I was right, so I went to Google and searched, ‘Animal classification of tiger’ and this is the first result. Here it is!” By pointing out a scientific genus and species name for a tiger, “*Panther tigris*,” and then searching online for its meaning, Ms. Randall shared the experience of realizing the system used for organism classification. Being informed about the classification of organisms helps one to understand the systematic way organisms are related. Furthermore, understanding that the natural world is organized into systems is an important feature of science literacy as identified in the NGSS and NSES (NGSS Lead States, 2013i; NRC, 1996). This example is a brief, yet important, example of the developing scientific literacy as part of multiliteracies.

Ms. Randall then presented a “challenge” to the class. Each student was asked to choose a mammal and then find and list the seven classifications of the animal in their lab notebooks. She gave students the option of working independently or with partners. The students quickly used their devices to find the classifications. In a focus group, I asked the students what process they used when searching for this information, as search directions were not specifically given by their teacher (Scientific Practice: Obtaining, Evaluating, and Communicating Information). Their responses are seen in the following quotes:

Chloe: I used my iPad and found this website that had all the answers.
Tish: I remember. I went to this, ‘animals for kids’ website and they had a search box.

Chloe: I think I went on Wikipedia. …

Alex: It’s also like, it’s easier to find better information, or easier information because there’s [are] some sites that have hard to understand information for us, but then some types are for kids that are good. …They’re easier to understand. We can understand some of the more, I don’t know, more advanced ones. But it’s just easier to find easy facts.

In another interview, Gabriella explained that she “just typed in ‘animal classification of otter.’” These were similar Google search keywords used by Ms. Randall in an example she used with the students in class. I also inquired about the students’ use of images on websites, to which they responded that pictures, especially with captions, helped them to “visualize what it does.”

After the students found the classification levels of their animal, Ms. Randall engaged the class in a discussion about things they “noticed” when searching for information. Student responses included, “The genus was a really long word,” “Instead of mammals it said Mammalia. I guess that’s the Latin word,” and “The website that I went to, everything was in Latin.” Because several students mentioned the Latin words, Ms. Randall connected the science concepts to the larger, global scientific community when she asked, “Why do you think scientists around the world try to use the Latin names?” One student responded, “Because all of them speak different languages, so they need one way to talk about them.”

Students in this lesson were engaged in obtaining information, and because there were multiple devices in the classroom, students were given a choice in the animals they chose to research and the websites they used to find the information. Students were exposed to the language of science in their search which became part of the learning experience as a result of
their interactions with the websites. They explored this language in different ways, as they were given few instructions and direction as to how and what to research. As typical in Ms. Randall’s class, students were asked to share their findings with their peers through classroom discussion and tasks such as the “Find someone else who…” activity.

Adaptation: Using websites and books as a model for student drawings. The use of visuals increased student involvement and ownership of learning as students both analyzed and created images and diagrams. After the assessment of prior knowledge and discussion about the phrase, “survival of the fittest,” the class interacted with a website about frogs to answer “adaptation questions” such as “How does it hide?” “How does it get its food?” and “Where does it survive?” The website used included images and text about frog adaptations. As students answered the questions, they referenced both the images and text in their responses. Ms. Randall read *How to Hide a Meadow Frog* aloud to the class. The picture book showed a frog camouflaged in different habitats, which was quite exciting to the students. On each page they searched and tried to point out the frog. Ms. Randall’s use of questioning and multimodal websites engaged students as they explored the role of adaption for living organisms.

Ms. Randall then displayed another website on the projector which showed adaptations of different animals. As she scrolled over the picture of an animal, a bubble would pop out over the body part to point out the different adaptation features. Before scrolling over each animal, Ms. Randall asked the students to observe the visual and then guess which features were adaptations. They looked at images of a grizzly bear, whale, caribou, and an eagle before closing the lesson with “Wrap-Up Questions.”

The next lesson began with the same learning target and review questions about animal adaptations. Ms. Randall also read another picture book aloud, *What Do You Do with a Tail Like*
This? Each page of the book showed “pieces” of an animal which students used to guess to what animal they belonged. The students guessed and then “ooohed” and “ahhhed” as the animals were revealed and explained. When asked about her use of websites and picture books in this unit, Ms. Randall expressed that she believed such tools are important in engaging students when they are not participating in hands-on activities:

[They are] very important. Especially since I’m not using as much real hands-on stuff. I want to make sure that I’m using a variety of sources so they’re seeing different things. Maybe a picture book will peak their interest or a website will.

Ms. Randall shared another website with the students in a similar exercise as was done the previous day. The class observed a picture of a sea otter and guessed why each identified body part was necessary in aiding the survival of the animal. Students were engaged and asked follow-up questions as they explored the animal. Gabriella explained, “[The otter website] was really cool because I didn’t know some of those things.” She enjoyed the website because of the pictures, as she explained, “It is easier for me to understand so if there is a word I don’t know in a paragraph or something, there may be a picture of it or maybe like a diagram.”

As part of the animal unit, students were required to complete a small adaptations project. Using library books and mobile devices, students researched an animal of their choice and created a small poster modeled after the animal websites explored in class. They drew their animal in its habitat, drew arrows pointing to parts of its body that represent adaptations, and then explained the adaptation in a text bubble. This “simple diagram” is an example of what Moline (2012) describes as a “picture glossary” or “diagram with labels” (p.51). Seeing an example on the websites was helpful for the students, as Chloe noted, “I thought that it helped. It
gave us an example of what it should look like. The otter thing is what it should look like.” The class went to the library where they were given time to find books, then returned to the classroom to continue researching and begin drawing. Students were given a rubric, which they stapled to the back of their poster. The students worked on this project for several days in class, and each day Ms. Randall restated the directions and reminded students of the key criteria of the project.

In the classroom, students used their library books and mobile devices as they continued researching their animal. Aaron stated that he enjoyed using both options because the book was less complicated, but a “Google search will have pages and pages of information. The books do too, but the computer has more information.”

Students again enjoyed being able to choose an animal to research, rather than being assigned one. Sam explained, “It’s so hard to do something that you might hate. Here you could pick an animal that you might actually want to learn about.” Aaron said, “If she just assigned us one and we didn’t want to do that one, we didn’t know that much. Or if we knew a lot about it we wouldn’t learn much.” Chloe stated, “If you didn’t enjoy it you wouldn’t want to do it as much and you wouldn’t care if you made a good grade or not, so it’s important to do something you like. Gabriella also suggested that choice gives voice when she noted that having choice gave her ownership of her presentation:

I get to decide what I want to do. Like when I’m looking up something or a presentation, I get to put what I want on there because it’s my presentation….If I did a presentation, like Ms. Randall, she couldn’t take control of that because it’s not her presentation.
Gabriella referenced ownership when creating work. If she created a presentation, it is her work, not her teacher’s. In addition to asking the students to choose an animal, Ms. Randall also gave students the freedom to add aspects to their project as well if they wished to do so. Gabriella asked in class if she could write a story instead of drawing a picture. Ms. Randall explained that the picture was required, but a story would be an excellent addition. Aaron mentioned this freedom in an interview:

I like the freedom. Like on projects if she said just make a poster it would be boring to see everyone make a poster. And like our projects because she gave us a little sheet and it said you can make a poster; you can make a play; you make a song; something like that or anything; and she gives us a lot of freedom to do how we want to do our project.

Aaron, similar to Gabriella, noted his appreciation for freedom and choice in classroom activities. This choice and freedom allowed students to express their voices through creativity, owning their ideas and best thinking while representing it in ways that were their own, as well.

**Metamorphosis: How to read and draw a cycle.** With the learning target on the board, “I can describe life cycles of various animals to include complete and incomplete metamorphosis,” Ms. Randall read *The Very Hungry Caterpillar* aloud to the class. Students were familiar with the term “metamorphosis” as the class apparently observed a lady bug metamorphosis earlier in the year in their classroom. Using a website on the projector, students took notes on the differences between complete and incomplete metamorphosis. On the following day, the class reviewed their definitions of the terms and then created a Venn diagram which they completed together as a class. The lesson continued with a card game, Go Bug (similar to Go Fish), where students worked in groups to create metamorphosis “sets” for
different animals. The metamorphosis sets were used in the next lesson as well, where students used websites (provided by Ms. Randall on Google Drive [2015]) to research the animal on the card and draw the metamorphosis cycle. Each student was responsible for drawing an incomplete and complete cycle. Ms. Randal demonstrated this process by drawing a cycle on the board. However, one student explained that her cycle looked “out of order” which spurred a conversation on why a cycle can begin with any stage. The student’s question was used as a stage to develop visual literacy of science diagrams, particularly “web diagrams” (Moline, 2012). Again, students were given a rubric to attach to their work.

Overall, Ms. Randall deemed the new animal unit a success as she reflected upon the unit:

It’s been difficult. I’ve enjoyed, I really have enjoyed it, but it’s difficult and I hope that I am, I feel like I am teaching the learning targets. I hope I am teaching them to the depth that we think they should be taught. I’ve looked at their four learning targets that I have to do with animals. I’ve taken each one and tried to involve a variety of different things. Making sure it’s introduced sort of in a fun way, that the kids do something. It’s harder to do hands on stuff with animals but that’s why they’re doing the little projects and things.

Through the activities, students were engaged in developing visual literacy skills as they interacted with online tools, teacher drawings, and then created diagrams of their own. With a great access to technology devices, students were often given the freedom to choose topics of interest and websites that were used to complete their projects.
Summary

This chapter explored the data collection in two cases—the classrooms of Ms. Tyson and Ms. Randall. Teacher backgrounds, teaching styles, and perceptions of multiliteracies, student voice, and scientific practices were presented along with classroom activities to show evidence of how and what multiliteracies and scientific practices were part of science in the classrooms. Student voices were interwoven into the narrative as multiliteracies and scientific practices surfaced. Specific examples of multiliteracies including visual literacy, collaboration, and the utilization of a variety of digital tools, online platforms, and resources dominated both science classes. All eight scientific practices were observed, though some more frequently than others. “Obtaining, evaluating, and communicating information,” for example, was observed more frequently than “Using mathematical and computational thinking” (NGSS Lead States, 2013c). Student voice emerged through the collaborative exercises, online communicative forums (e.g. Google Drive [2015] and Schoology [2015]), and student choice to name a few.

Data analysis revealed iterative patterns with four emergent themes. Within the classroom narratives provided, the first theme emerged: The modern classroom for science and technology: Teaching and learning in the shadows of time, standards, and testing. The term “modern” is used to describe two aspects of today’s classrooms—the integration and development of multiliteracies, and the impact of high-stakes testing and teacher accountability. The narratives continued with an extensive look at classroom practices and experiences (as described by teachers, students, and classroom observations). Within this portion of the narrative, the other two major themes arose: First, science classroom experiences that utilize multiliteracies (e.g. visual literacy, collaborative learning, use of technology, problem solving) are breeding grounds for student voice. Second, the integration of scientific practices with technology and
communication creates a platform that develops both scientific literacy and multiliteracies. Throughout the findings student voices were engaged through interviews and focus groups. The wisdom imparted by students was inspiring and profound, providing support for the fourth theme, “Student voices: Under construction and heard.” In the following chapter, these themes are discussed and developed further.
CHAPTER 5—DISCUSSION AND CONCLUSIONS

In the previous chapter, the findings of a multiple case study in two science elementary classrooms, taught by Ms. Randall and Ms. Tyson, were presented as the following research questions were explored:

1. What and how are multiliteracies, science, and scientific practices implemented in the elementary science classroom?

2. With respect to learning science and scientific practices in the classrooms of study, how are student voices engaged through multiliteracies?

3. How do teachers and students perceive multiliteracies, student voice, science, and scientific practices as they are enacted in the classroom?

The narratives, though rich, are only snapshots of multiliteracies, student voice, and scientific practices as they unfolded in the classrooms. After extensive coding of data from each case, an analysis of categories and subcategories continued until themes across the cases emerged (Charmaz, 2006; Stake, 2006). After providing a detailed, thick description of each case in chapter four, this chapter discusses the major themes that emerged across the cases, followed by conclusions and implications for changes in K-12 and teacher education.

Jacobs (2013b) emphasizes the notion that multiliteracies “refer not only to the multiple modes through which people engage in ideas, but also to the multiple contexts in which language is used as well as the multiple factors that contribute to the make-up of those contexts” (p. 270).
The New London Group separates the *what*, *how* and *why* of multiliteracies pedagogy. As Jacobs (2013b) noted, the *what* of multiliteracies encompasses multimodality which includes a variety of design features: linguistic, visual, audio, gestural, and spatial (New London Group, 1996). The *how* is described through four pedagogical practices. The first two, Situated Practice and Overt Instruction, require “immersion in meaningful practices within a community of learners who are capable of playing multiple and different roles based on their backgrounds and experiences” while being guided by the teacher when necessary through scaffold learning (New London Group, 1996, p. 21). Critical Framing requires that students critically examine information from a variety of “historical, social, cultural, political, ideological, and value-centered perspectives” (New London Group, 1996, p. 22). Finally, Transformed Practice requires the implementation of ideas and knowledge in new areas (New London Group, 1996). The *why* of multiliteracies results from a changing world, inundated with technological advances and a new, fast-paced capitalism, and global connectedness (Gee, 2000). This study addressed all three avenues (*what*, *how*, and *why*) of multiliteracies in two elementary science classrooms through the voices of teachers and students. A changing world with changing students means a change in student needs in classrooms. Who better to share the needs of students with educators than the students themselves? This study addressed not only if and how multiliteracies influenced emergence and character of student voices in elementary science classrooms, but how students perceive classroom practices related to multiliteracies through focus groups and interviews.

In this study, the previous National Science Standards (NRC,1996) as well as the Next Generation Science Standards (NGSS Lead States, 2013i) provided a platform for addressing multiliteracies and student voice through its advocacy of inquiry, scientific and engineering practices for problem solving, and technologies though that was not the intent. In addition to
being able to conduct scientific investigations, students of the modern classroom should be able
to efficiently and effectively locate, evaluate, and communicate information in a variety of ways
from a variety of sources (NGSS Lead States, 2013i). Understanding science as well as
engineering and their practices, traditionally practiced by scientists and engineers, has become
easier and will continue to gain momentum in K-12 classrooms because access to such content is
readily accessible outside of the classroom through the internet and mobile devices (NGSS Lead
States, 2013c). Access to technologies outside the classroom in the learners’ social and familial
cultures nudges similar changes within the cultural institutions we call schools which are slow to
change (Collins & Halverson, 2009). This conjunction of multiliteracies, scientific practices, and
student voice, though fluid and adaptive, was apparent in both classrooms of study.

**Discussion of Themes**

The discussion draws on the findings presented in chapter four, with each theme bringing
together the words and events of the participants to draw out what and how multiliteracies were
revealed in its various dimensions, and how these were associated with student voice and
scientific practices.

**Theme 1: Science Classroom Experiences that Utilized Specific Multiliteracies are
Breeding Grounds for Student Voice**

A springboard for student voice was found within the use of specific multiliteracies that
were implemented within both elementary science classrooms in a variety of forms including the
development of visual literacies, distributed practices, problem-solving investigations, and the
utilization of technological devices. As these practices were enacted, “student voices as
perspective” (i.e. opinions and beliefs) along with “student voices as participation” (i.e.
engagement and student choice) were engaged and developed (Furman & Barton, 2006). What follows portrays multiliteracies observed in the classrooms as they converged with scientific practices to provide a “breeding ground” for student voice in science.

A key feature of multiliteracies is the ability to decode and make meaning from a variety of media including traditional text, online text/webpages, video, images, and diagrams (Kress, 2003). During both science classes, students interacted with an array of visuals including diagrams, online images, textbook images, animated and realistic videos, comic strips, computer software, and physical models. As the students engaged in science, they interacted frequently with these image-rich resources which created circumstances in which students seemed more engaged, excited, and interested in learning. Students from both classes were quite adamant that visuals, particularly videos, were a suitable alternative to traditional textbooks. They noted that videos such as BrainPop (2015) and Science Court (Scholastic, 2015) had characteristics of being quick, engaging, humorous, and valuable because, according to the students, they allow more time to be allocated to “interactive” science activities. Chloe, in a focus group, explained that she liked BrainPop (2015) videos saying, “Those are nice because it’s the 21st century and nobody likes to read out of a textbook anymore.” The other students in her focus group agreed. Stephen found that the videos were “funny” and students pay more attention to them. Mirroring their teachers’ desire to use varying strategies to reach all of the students, Alex said having “options” like these, as well as a variety of tools in class, was his preference when learning.

Students embraced “variety” as the preferred modus operandi for learning science. In both classrooms, they were quick to voice their opinions about videos as visuals in learning with comments like, “It’s fun and educational” referring to BrainPop (2015), or “It’s a good way to learn because it has some humor in it, but it’s also a visual presentation” when describing
Science Court (Scholastic, 2015). Listening to them, it seems that experiences in science that are “fun” and “educational” are rare and seen as a novelty in school. What is a bit surprising is that television and movies use visuals for learning and entertainment outside of school daily, yet visuals that are “fun” and “educational” have yet to be an important part of these students’ science education. It is still a novelty in classrooms, though these visuals have been part of the culture for over sixty years (Collins & Halverson, 2009). In these classrooms, “fun and educational,” videos were frequently a part of the learning process and evoked the voices of the students who held clear opinions of what works for them when learning science. Utilizing videos and interactive software such as Science Court (Scholastic, 2015) engaged the students, leading to greater effort in their science class and fostered visual literacy, though neither the teachers nor students mentioned the term visual literacy. Callie, however, explained the importance of visuals when learning science:

I think the pictures do help, but hearing it is probably the hardest part. When she’s telling it to you, you have to imagine it yourself and you’re maybe not always right. […] Because then [with images] you can see how they really look and it just kind of looks a little more connected and easier to see. So it helps to be a little more interesting like that.

Callie clearly voiced that she finds images and diagrams as a preferred tool for the visualization of science content that is difficult to understand (Coleman, Bradley & Donovan, 2012; Coleman & Goldston, 2012).

Utilizing visual literacy in learning may occur as either interpretation or production. Both types were noted throughout the study, though interpretation of visuals was more prevalent in the study’s classrooms (Lundy & Stephens, 2015; Moline, 2012). Students in Ms. Tyson’s
class developed visual literacy skills as they frequently engaged with visuals to interpret and discuss what they viewed (e.g. videos, software, textbook diagrams). Other times the visuals were used to engage students (e.g. Science Court), or to draw attention to particular scientific concepts (e.g. water cycle diagram). Students in Ms. Tyson’s class rarely participated in the production form of visual literacy. The only instance in which students created visuals occurred in the Toothpick Bridge Project where the students drew plans, created a model, and produced a real-life perspective drawing of their bridges. Students voiced that visualizing what their bridge would look like in the real world was the most difficult task in the project.

In Ms. Randall’s class, production of visuals by students which enhances visual literacy was a part of many science lessons. Students in her class found drawing diagrams and images to be an effective way to communicate their ideas and voice in science. The phrase, “a picture is worth a 1000 words” rings true, as students explained that visuals help them to see and share their ideas rather than having to infer an idea from text alone. Aaron described the importance of visuals in science while discussing the purpose of drawing the circuit as well as writing about it. He said, “Well, when people are saying it you can [try to] visualize it. When you write about it, they can visualize it in their head. But when you draw it, they can just see what it was.” Students’ insights into the process of drawing and its place in learning is clear when asked why they drew diagrams of the circuit they created during the Make it Light activity. They said that visual images were important so “we can remember,” or “you have to see with your eyes.” Destiny went a bit further saying, “Yeah and people have different stuff [ideas in their mind] so it’s easy to see [when drawn].” She described an important connection between visual literacy and voice. Students have “different stuff” (ideas and thought in their heads) and creating a visual
makes those ideas easier for others “to see and understand.” Accordingly, students view visual production as an alternative format that can give rise to voice.

Even though they did not use the term, visual literacy, the students held keen insights into how it influences their science learning. In the Make it Light activity, the students were not receiving information in a visual form, but rather creating their own images (by drawing diagrams) to describe and share the electrical circuit they figured out. Thus, the students shared their opinions about effective ways of learning science that included visual literacy, fostering a different kind of communication, the strong silent voice of images that is based in “seeing.” (Felten, 2008; Moline, 2012)

The use of visual design, along with other important multiliteracy practices, was also evident in investigative, problem-solving activities. In both science classrooms, students participated in investigative activities that incorporated inquiry-based practices that ranged from directed to guided inquiry (Gabel, 2006). The practices implemented through problem solving activities included persistence and effective communication that fostered multiliteracies and student voice simultaneously (Broderick, 2014). During investigative and problem solving activities, multiple voices and perspectives were heard and valued as there were often more than one way to view and address the problem.

As with the use of visuals, many students preferred learning science through investigative activities, engaging in problem solving, and interactive learning. Students found activities and investigations not only more enjoyable, but a more effective and efficient way to learn. When I asked Kevin if he could do anything in science, what would he do? He responded by saying, “Experiments…Probably because some people learn a lot more when they’re having fun. I do
that myself.” Callie agreed, “I would want [students] to get involved, like not just sitting at their desk hearing about it. …Because then you remember the experience… you learn more on your own so it kind of sticks more.” She continued,

If the teachers tell you “Don’t make this mistake,” and you don’t make it, then you never really learn anything. You just didn’t make a mistake. But when you make the mistake and you fix it, then you know what to do when that happens and how to start over.

Students spoke of ‘choice’ as a skill that warrants practice in the classroom. In their diverse voices, they articulated that making choices and mistakes were integral skills for learning and future success. In multiliteracies research, these are critical skills that contribute to the development of a “portfolio person” who is able to work flexibly on a variety of problems, adapt to varying situations, and think critically (Gee, 2000). Students stated in their own words the connection between multiliteracies and student voice. “Student voice as participation” through choice and the freedom to make mistakes not only situates ownership of learning, but assists them in developing critical skills associated with multiliteracies that are recognized as important for the future (Furman & Barton, 2006). Investigative activities appear to be one way in which to develop these skills.

During investigative and problem solving activities, evidence of student voice emerged through student questioning. In the Will it Float activity, for instance Kevin asked, “What would happen if we peeled the lime?” During the Toothpick Bridge project students asked questions including, “What if we put the sides together first and then put on the top?” Increased student questioning during problem-solving or investigative activities served as an example of “student voice as participation,” and it was clearly evident during each investigation observed (Furman &
Barton, 2006). Students were aware and reported not only being more engaged during problem solving, but they felt that they indeed learned more. Asia, may have said it best, “You don’t actually get it, what you’re learning in a book, because it just gives you the answer. So you have to memorize it. But if you find it out yourself you technically already know it.” Problem solving through investigations in science fostered student voice and multiliteracies by requiring students to actively construct their own knowledge rather than passively receiving information from the teacher or textbook (Brooks & Brooks, 1999; Glynn & Muth, 1994; Martin, 2012). This constructivist perspective to teaching and learning fostered the development of student voices not only through participation (e.g. choice and engagement), but student voice as unique perspectives and opinions of value (Fosnot, 1996; Furman & Barton, 2006). The process of problem solving by its nature inherently validates the value of varying perspectives and ideas. Therefore, the cultivation of student voices is an imperative and undistinguishable component in the development of the multiliteracies “portfolio person” (Gee, 2000).

Within the investigative activities, students were given the opportunity to work collaboratively with their peers. Collaborative, communicative practices in science classrooms are inherently multimodal (Lemke, 1998; Nixon & Smith, 2015; Prain & Waldrip, 2006). Nixon and Smith (2015) argue that students are “asked to negotiate a wide variety of modes in quick succession” including “spoken words and gestures” of the teacher and classmates (p. 188). Students use “Available Designs,” to “Design” and “Redesign” between modes, a central component of multiliteracies (Marenzi & Zerr, 2012, p. 337; New London Group, 1996). Furthermore, during collaborative exercises, students were able to explore each other’s strengths and weaknesses, challenge each other’s ideas, and take charge of their learning. For example, Gabriella chose bighorn sheep as the topic of study for her project, though she asked a friend to
complete the drawing for her. She admitted that she knew her friend was a “good drawer” so she asked her for help. In an interview, Ms. Randall explained that even though she encouraged Gabriella to draw the animal herself, she did not discourage the other student from helping because collaboration is an important skill to learn. Knowing one’s strengths and weaknesses, as well as those we work with, allows and encourages the sharing of talents in a work environment to create the best product or outcome. This is an example of multiliteracies in action in the classroom, and in preparation of distributed systems in the future workplace (Gee, 2000). In such distributed systems, workers collaborate seamlessly and adaptably with each other, using each individual’s skills to benefit the whole group (Gee, 2000). In this instance, one student’s artistic talents were utilized by another to create a final product.

The realization of self as a participant of the classroom, society, and global community is essential in preparing students for the broader society which is becoming increasingly diverse (Giampapa, 2010; New London Group, 1996). Broderick (2014) notes the connections in participatory culture and multiliteracies pedagogy which “has the potential to democratize learning spaces and support collaborative environments where students’ roles move back and forth between learner, teacher, and leader” (p. 200). Participatory culture, defined as a “culture with relatively low barriers to artistic expression and civic engagement, strong support for creating and sharing creations […] where members also believe their contributions matter and feel some degree of social connection with each other” (Jenkins, Purushotma, Weigel, Clinton, & Robison, 2009, p. 9-10), combined with multiliteracies pedagogy, results in what Broderick coins “collaborative design” (2014). Collaborative design has the potential to “bring together the technical aspects of multiliteracies, including design and redesign, with key features of participatory culture” (Broderick, 2014, p. 203).
The students of Ms. Tyson’s class expressed clear awareness of themselves as individuals and as part of a whole when they discussed collaborative learning. Student collaboration was an area of contention between some students. Some students preferred to work alone, others preferred to work in groups. Still other students clarified that smaller groups were better than larger groups. It was clear, though, that they understood the importance and value of working collaboratively with their peers (Broderick, 2014; Johnson & Johnson, 1989, 1999). The majority of the students agreed that working together was efficient and resulted in better understanding and higher quality work. Kevin, who generally lacked confidence, suggested that working with others was helpful in understanding and completing activities:

If I am doing something and I look at the instructions but this doesn’t look right [pause] probably because I am not really working with someone else. Someone else would point out what I missed.

In support of Kevin’s comments on collaboration with peers, students in focus groups also attested to the benefits of working collaboratively, particularly during classroom activities that utilized scientific practices and multiliteracies. The following are excerpts from a lengthy conversation with a fifth grade focus group. The students addressed several considerations of collaborative learning such as ease of working with peers, efficiency, effectiveness, and implications for future employment. Aware that as participants in a culture different from adults, they found working with their peers was a beneficial practice. For example, Asia, said, “Yeah, because we know how each other ‘talks.’” Other students pointed out that they understand each other’s “slang” and that it is sometimes “hard to talk to adults.”
In addition to working with peers, Harold found collaboration created an effective and efficient learning environment. He stated that it was more effective “because you can get more work done.” Furthermore, he said, “You can also talk and if someone makes a mistake you can talk about it. If you make a mistake by yourself, no one can help you.” By identifying processes of learning through making mistakes, helping others, learning more, and being effective, the students are engaging in multiliteracies as integral practices acted upon in their science classrooms. These statements also identify students as voices of authority and recognizing the power they have over their own learning preferences. They clearly believe that they have the ability to assist each other in learning processes that extend or go beyond the scope of what a teacher is capable of doing alone.

Perhaps one of the most powerful kinds of knowledge students revealed, is that they are acutely aware of how collaborating with or through technology affects their lives today and potentially in the future. Several students (“digital natives”) remarked on their knowledge and ability to assist their parents (“digital immigrants”) in their usage of technology. “Digital natives,” first defined by Prensky (2001), are “‘native speakers’ of the digital language of computers, video games, and the Internet” as they have “spent their entire lives surrounded by and using computers, video games, digital music players, video cams, cell phones, and all the other toys and tools of the digital age” (p. 1). “Digital immigrants,” on the other hand, “were not born into the digital world but have, at some point later in our lives, become fascinated by and adopted many or most aspects of the new technology” (Prensky, 2001, p. 1-3). Sarah Ann shared an anecdote from her personal life, sharing, “I taught [my mom] how to screen shot something today.” To which her mother replied, “I don’t know what you just said, but it’s cool.” Callie added to the conversation, “But a lot of kids, we can teach parents stuff. It’s really cool like,
older parents use their phone and stuff, but kids get it.” Not only did students express their proficiency with technology, but they divulged that technology can be a better tool for communication and working with others. Kathryn commented on her preference to communicate through technology when in uncomfortable situations. She admitted that she “will put more in texting than you would say in person” because you “can show more of your personality.” For students that may lack confidence communicating orally, technology offers a valid, less-threatening alternative.

The students are clear about the differences in the cultural worlds of adults and themselves and how they participate within them, and they recognize that they are able to assist each other in a way that adults cannot. Though collaboration with peers has long been viewed as a beneficial practice for students, this generation of students, having grown up with technologies literally at their fingertips, provide a new way to envision the role of the “teacher.” Students now collaborate in a variety of ways. Donovan, Green, and Mason (2014) argue that “at times, it is difficult to determine who owns the technology (e.g. laptop) being used. Students most often are sitting in a circle or standing leaning over each other at the desk of one or two students” (p. 173). In classrooms, process has always been important in science, but the teacher or text was heavily relied upon to provide content. With content now readily available in many forms online, and students identifying each other as valuable resources when locating, evaluating, and interacting with information, the teacher’s role can be one that is now shifting or expanding from being the sole source of knowledge, to the architect and organizer of multiple sources for learning experiences which embrace the gamut of digital technologies.

As the organizer of multiple sources for learning experiences, knowledge of effective integration of technology in the classroom is paramount (Blackwell, Lauricella, Wartella, Robb,
Teachers and students in this study utilized mobile devices (e.g. tablets, phones, iTouches) to quickly research information in science. Both teachers noted that the internet was a useful, quick resource for their classrooms. In Ms. Randall’s class, the use of multiple devices offered students choices in selecting an animal to be researched in several activities. Sam said it was beneficial because “you could pick an animal that you actually want to learn about.” Many students agreed that having a choice was freedom to study an organism of interest to them. In both classes, students used mobile devices and the internet in circumstances where they were prompted by their teacher to do so, but also in unprompted instances as well. Students were not only given choice in what they researched, but how they researched. It appears that in the students’ culture, a shift from seeking books for information to using the internet is complete. Although books are an important resource, the internet is the tool of instant access with a click or touch. The internet opens to what appears to be a limitless amount of information (Collins & Halverson, 2009; Gee, 2013). Not only is information constantly and readily available through technology and websites, but the avenues in which students acquire new content (e.g. Google and Wikipedia) frequently reveal exploration of connected and related topics which the students may never have considered (or never found with books) without such prompting. Discussion among students about websites revealed a contention among students in determining websites they perceived were useful. Some students stated that they enjoyed “kid” websites; while others preferred more “adult” content websites. Other students enjoyed websites such as Wikipedia, whereas a few voiced that the information on user-generated content sites was unreliable. No matter their stance on site evaluations, when utilizing multiple devices, students are free to explore, evaluate, and use websites they deem
fitting for their personal learning style and task (Collins & Halverson, 2009; Dunleavy, Dexter, & Heinecket, 2007).

Summarizing theme one, it is clear that multiliteracies in the two science classrooms studied were evident in visual literacy practices, collaborative exercises, investigative activities, and technology use. Furthermore, as students participated in these activities, they reported feeling more engaged and empowered with what and how they were learning. Ms. Randall and Ms. Tyson expressed positive and negative views of various aspects of multiliteracies, which will be discussed in the next theme. Science classroom experiences that implement multiliteracies such as visual literacy, collaborative learning, technology, and problem solving appear to be breeding grounds fertile for the growth of student voice by owning their knowledge and skills in a collaborative culture as they engaged in meaningful conversation. Addressing again the why of multiliteracies, becoming a “portfolio person” requires that a person be able to adapt, accessing “rearrangeable skills acquired in their trajectory through ‘project space’—that is all the projects they have been in” (Gee, 2000, p. 45). If this is the case, then experience in “projects,” or meaningful classroom activities in this case, is quite important as a way to develop multiliteracies. In Norton’s interview of Tapscott, the “Net Generation” (people born after 1977) “are natural collaborators, who enjoy conversation, not a lecture. They’ll scrutinize you and your organization. They insist on integrity. They want to have fun, even at work and at school. Speed is normal, innovation is part of life” (Norton, 2010, p. 29). Scientific practices incorporated in scientific investigative activities, along with multiliteracies design, encouraged students to be active participants in their learning, constructing, and owning knowledge. Breeding grounds for student voice were fostered by multiliteracies such as technologies, visual literacy, and
collaboration. By its nature, science (scientific practices, investigative activities, problem-based activities) is a natural venue for this process to occur.

**Theme 2: The Integration of Scientific Practices with Technology and Communication**

**Creates a Platform that Develops Scientific Literacy as a Multiliteracy**

The Next Generation Science Standards (NGSS) identify eight scientific and engineering practices that all students should experience and learn during their K-12 science education (See p. 26-27). The intent of the national and state standards is for teachers to use these practices when teaching content. Furthermore, when the practices are implemented effectively, they are integrated seamlessly while teaching disciplinary core ideas of the sciences.

Inquiry activities in science education range from directed inquiry to full inquiry. On one end of the continuum is directed (or structured) inquiry, in which the teacher generates the question, provides procedures, gives students the data and directions on how to analyze it, and then gives directions on how to communicate ideas. This type of inquiry gives students minimal choice and is often used as a starting place in early engagements with investigative activities or to simply teach a given concept. Therefore, directed inquiry is the most teacher centered form of inquiry. Gabel (2006) suggests utilizing directed inquiry as a means to prepare or scaffold students for more complex tasks, particularly when beginning new concepts. Moving toward the middle of the continuum are various forms of guided inquiry. With guided inquiry, the teacher releases some control, giving students more choice with respect to the key features of inquiry defined as “a) engaging with a scientific question, b) participating in and developing the procedures, c) giving priority to evidence, d) formulating explanations, e) connecting explanations to scientific knowledge, and f) communicating as well as justifying explanations”
During the guided inquiry the teacher may offer choices or allow student choice on some of the features, but still guides the overall investigation. In this study, the curriculum kits used and referred to as Alabama Math, Science and Technology Initiative (AMSTI, 2013) kits, were primarily guided or directed inquiry and a primary resource used in Ms. Randall’s class. During guided investigations, such as the Make it Light activity, the teacher asked guiding questions challenging students to explore an idea further in their own ways. Full (or open) inquiry is at the opposite end of the continuum from directed inquiry. Full inquiry in theory is totally student-centered in its approach, though rarely enacted in the reality of a classroom. It may begin with a student-generated question and then give students the opportunity to design and carry out investigations or experiments, collect data, and communicate their results and/or arguments. Full inquiry was not observed in either classroom. The closest they came to full inquiry was with the engineering bridge design.

As was described earlier, sophisticated student questions arose during the directed and guided inquiry activities, this represents the scientific practice of “Asking questions (for science) and identifying problems (for engineering)” (NGSS Lead States, 2013c). For example, in Ms. Tyson’s class, students frequently asked questions of each other during the Toothpick Bridge project as they planned, tested, and redesigned their bridges. Student questions also resulted from interactions with visually-rich resources. Students in Ms. Randall’s class asked questions about the animals they observed on interactive websites. Often, this led to the creation and use of many “tools” to “develop questions, predictions, and explanations…and communicate ideas” in the enactment of the scientific practice of “Developing and using models” (NGSS Lead States, 2013c, p. 6). These tools can include “diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations” (NGSS Lead States, 2013c, p. 6). In Ms.
Tyson’s class, students designed and built models of bridges during the Toothpick Bridge project. Ms. Randall’s students drew a diagram modeled after a website which identified and labeled adaptations of animals. The students also drew the successful electrical circuit configuration in the Make it Light activity. In many circumstances, the models or diagrams created by students were in reference to other images found either in books or on the internet. Both asking questions and utilizing models are important practices in the development of scientific literacy. Furthermore, both scientific practices are also evidence of student voice as students are the active participants in the creation of questions and models (Furman & Barton, 2006). When discussing the bridge model, for example, Callie enthusiastically voiced that “the teacher can’t tell you to ‘make it like this design’ because it’s your design.”

Incorporating many key features of guided and full inquiry mentioned above, the scientific practice of “planning and carrying out of investigations,” particularly investigations that “emerge from students’ own questions,” requires that students “design investigations that generate data to provide evidence to support claims” (NGSS Lead States, 2013c, p. 7). The NGSS suggest that students should participate in investigations that span the inquiry continuum “at all levels” from kindergarten through high school (NGSS Lead States, 2013c, p. 7). In Ms. Tyson’s class, students orally described a plan for an investigation during Science Court. However, the investigations were never carried out. Unfortunately, this was a missed opportunity for students to fully explore their questions. Ms. Randall’s students participated in the Make It Light activity, an AMSTI (2013) lesson, as they created hypotheses and recorded observations and explanations. This guided inquiry activity gave students the opportunity to use and gain skills in scientific practices while still under the guidance of Ms. Randall.
A critical practice in inquiry activities is the practice of “analyzing and interpreting data” as students “reveal patterns and relationships” in science or “analyze designs” in engineering (NGSS Lead States, 2013, p. 9). Students in Ms. Tyson’s class analyzed and interpreted data informally through their Toothpick Bridge design testing. After the bridges were tested for strength, the students gathered around their designs and discussed which design features were successful and which were not. This is a key feature of data analysis and interpretation for engineering. As stated by the NGSS, “This allows comparison of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem with given constraints” (2013c, p. 9). During the Make it Light activity, students analyzed data as they tested and retested circuit configurations in Ms. Randall’s class. There was evidence that students were engaged in data analysis and interpretation during other times of the day, as well. For example, charts displayed on the walls contained student-created graphs documenting the medals won by varying countries in the Olympics, which were taking place during the time of the study. The ability to analyze and interpret data is a practice that, although taught frequently in science and math classes, can be transferred into a variety of situations to serve many purposes. Besides being able to analyze information and data in science, this practice is a part of daily life with respect to multimedia, news outlets, social media, and advertisements which is an important multiliteracy (Collins & Halverson, 2009; Gee, 2013).

Many concepts taught in the science classroom require mathematical and computational skills for full comprehension of science concepts (NGSS Lead States, 2013c). Students used mathematical and computational thinking through scale and measurement practices during the Toothpick Bridge project in Ms. Tyson’s class. They also participated in a brief mathematical experience during a classroom discussion about the components of the earth’s atmosphere. Ms.
Tyson asked, “Our atmosphere is eight-tenths nitrogen, what percentage is that?” One student blurted, “Ugh, I don’t want to do math.” Ms. Tyson continued, “Two-tenths is oxygen. I know that should equal 100% but there are a few things in our atmosphere that make up such a small amount that they don’t even make up a percent.” No evidence of mathematical practices in Ms. Randall’s science classroom was observed, although student math work was frequently displayed on the chalkboard.

Building upon the analysis of data and mathematical computations, students are expected to construct explanations or design solutions for the questions or problem being considered (NGSS Lead States, 2013c). Constructing explanations and designing solutions in science and engineering was, like many of the other practices, most prevalent in investigative activities that utilized collaborative learning. In these instances, students were given the opportunity to communicate their ideas when prompted by questions from each other or their teachers. As the students stated, constructing explanations and designing solutions with each other was an effective practice. When constructing explanations or solving problems, having multiple voices and tools as resources enabled students to evaluate the voiced ideas against their own, judge the other ideas as more compelling or not than their own, and determine their own stance. This built confidence and skills needed for lifelong learning (NRC, 2012). The scientific practice of constructing explanations and designing solutions, especially when done in collaborative settings, mirrors the notion of “distributed systems” where leaders “facilitate and mediate,” and “networks form and reform on demand” (Gee, 2000, p. 45). Here again, collaboration on projects with scientific practices develop scientific literacy, and such practices are readily transferred into other experiences outside of science.
Key to presenting findings in science is being able to support an explanation or solution with evidence. In Ms. Tyson’s class, students engaged in argument from evidence during the Science Court computer software program. Students utilized the information and evidence provided through the program (videos and text resources) to argue “guilty” or “not guilty” as the culminating activity of the unit. They also engaged in argument as they deciphered a water cycle diagram in the science textbook. Ms. Tyson asked, “Is water that has evaporated still water? What about ice, is it still water? Let me hear your arguments.” In Ms. Randall’s class, students engaged in argument from evidence in one of the electricity investigations. When provided several diagram configurations of possible circuits, students worked in pairs to test the configurations with their light bulb, wire, and battery identifying which ones would light and which ones would not. After the activity in a class discussion, students shared their “disagreements” and “arguments” with the class. One student shared, “I think I know why this one would work. At first we thought it wouldn’t work because [the wire] was on the side, but then we realized that the side part of the light bulb is metal too, so it should work and it did.”

When working in distributed systems, being able to “argue” effectively with evidence is an important feature of multiliteracies (Gee, 2000). First, one must make meaning from various texts, images, or investigative data, then formulate an explanation and argument based on collected evidence. Once claims are ready to be made, they must again be transformed into language that fits (or benefits) the system. To accomplish this requires acute attention to diversity and characteristics of team members, community practices, and language/information sources and reliability.

Depending on the purpose, inquiry activities often involve students “obtaining, evaluating and communicating information” from either their investigations or from other resources (NGSS
Lead States, 2013c, p. 15). It is becoming increasingly important that students become “critical consumers of information about science and engineering” (NGSS Lead States, 2013c, p. 15). In both classes, students obtained information from a variety of sources including books and online websites. In several of the science classroom activities, students participated in varying ways obtaining, evaluating, and communicating information. Obtaining information varied in resource selection, choosing from the teacher-provided materials, locating books in the library, to researching online. Evaluating information varied as well, from simple analysis and discussion to examining the validity of websites. Overall, this scientific practice is becoming increasingly complex when transferred because of the Internet. When interacting with information on the Internet students are not only evaluating traditional expository text; but images and user generated content (Gee, 2013; Kress, 2003). One of the joys of the Internet is that content can be originated by practically anyone. This poses a unique threat to information validity and reliability (Gee, 2013). The students were aware of this, so it makes them wise consumers of the information available to them.

Important to scientific literacy is the ability to discern for oneself the value and credibility of information and sources, a practice which must now be developed with the inclusion of technological resources as is described in multiliteracies literature (Knobel & Lankshear, 2000; NSES, 1996). Although on the surface it appeared that little “evaluation” was occurring, the students evaluated information constantly, as was noted earlier in the Researching Online discussion in the previous chapter. Although students were not explicitly directed to evaluate resources in class, during focus groups and interviews it became apparent that the students did, indeed, evaluate the effectiveness of text, images, and diagrams in their textbook and online without being prompted. When we discussed this process, students explained how they navigate
online from choosing websites from a Google list to whether or not they trusted Wikipedia as a reliable source. However, evaluation of science content against outside criteria was not specifically observed. Given their youth, these students portrayed sophisticated skills when it came to understanding and navigating the internet—not only in ability, but in cognitively sorting through what was credible and what was not.

When the science activities were enriched with multiliteracies (particularly information technologies) and scientific practices appropriate to the tasks, students were actively developing skills and knowledge to be considered a scientifically literate individual. Though scientific literacy is not specifically identified as part of multiliteracies as discussed in the literature, through this study and the connections made, it is indeed part of the broader view of multiliteracies by its association with technologies, problem solving, and scientific practices. The *National Science Education Standards (NSES)* (NRC, 1996), describe scientific literacy as “the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity and includes specific types of abilities” (1996, p. 22). The “abilities” referred to are quite similar to the scientific and engineering practices advocated by the NGSS (NGSS Lead States, 2013f). Not only are the methods in which we can engage students in these scientific practices changing through technological innovations, but the conditions through “civic and cultural affairs” for which we are promoting scientific literacy are evolving as well (NRC, 1996). In the broadest sense, technologies, scientific practices, and problem solving are entities of science that flow back and forth into and out of each other well beyond the classroom doors. Developing scientific literacy requires one to have an ability to understand how these entities interact within the world and societies. Thus, this study establishes that characteristics of scientific literacy, by its intent
and purpose, are a form of multiliteracies. Thus, teaching and learning of science and its practices for scientific literacy is in fact, reinforcing the development of broader multiliteracies.

Weinstein (2006) grapples with the notion of scientific multiliteracies, though, in a way quite different from this study, as he “holds onto a more literal sense of scientific literacy as a reading and writing practice” (p. 610). His work gives little attention to the scientific practices and doing of science, aside from reading and writing. I argue that scientific literacy, and therefore scientific multiliteracy, requires not only meaning-making from text and other design features, but it also involves the conjunction of text with the scientific practices and multiliteracies such as communication and interaction with technologies. Weinstein (2006) does, however, address an important consideration of scientific literacy with a majority of students that will not be future scientists. He argues that positioning students “in varied material and affective relations with the laboratory” will “provide the grounds for a science education that might actually speak compellingly to all students” (Weinstein, 2006, p. 618). During the Toothpick Bridge Project, for example, students were exploring science and mathematics concepts (content) through researching bridges online and constructing a model, though they were also positioning themselves as active creators, members of a team, and problem solvers. By participating in “varied material and affective relations,” making meaning and communicating with multimodal design (gestural, spatial, visual, audio, and linguistic), students were actively involved in developing scientific multiliteracy (Weinstein, 2006, p. 618; New London Group, 1996).

Developing scientific literacy within individuals, in part, means they must be able to “describe, explain, and predict natural phenomena” (NSES, 1996, p. 22). With respect to acquiring multiliteracies, it is clear that the implementation of scientific practices in classroom activities supports the process. For instance, as students shared questions and explanations with
each other during investigative activities, student voice was engaged in several ways. In the Will it Float activities, for example, student voice was exhibited when asking questions in science that led to a feeling of empowerment and confidence for Kevin, an emotion he admitted to not experiencing very often in math and science. Although the buoyancy activity was implemented as a whole-class demonstration, the use of questioning by the teacher and students impacted not only the learning of content, but student engagement and confidence as well. This, in turn, creates a “culture of wonder,” a climate more conducive to supporting students’ voices as they construct and share explanations in science (Rabbat, 2014, p. 36).

Although engineering practices were not a focus of this study, activities such as the Toothpick Bridge Project did in fact engage students in engineering practices. Engineering activities are not only engaging for students, but they can increase student learning in math and science (Moore, Tank, Glancy, & Kersten, 2015; Brophy, Klein, Portsmore, & Rogers, 2008). Furthermore, it aids students in understanding the possibilities of careers in science and engineering. Gabriella, when asked what she would like to learn about in science, responded by saying “Scientists and what they do…Because I’ve always wondered what scientists really do. I know they discover and look at things, but I wonder what they really do.” If students are given opportunities to engage with science and engineering in ways that mirror what scientists and engineers “really do,” then not only can such activities move them toward greater scientific literacy, but open doors for future investigations and employment. As noted, the practices needed for scientific literacy mirror many of the features described in multiliteracies research which places scientific literacy as a multiliteracy (NSES, 1996; New London Group, 1996; Gee, 2000, 2000; Knobel & Lankshear, 2000). In becoming scientifically literate, students are required to make meaning from an array of multimodal design features including linguistic, audio, visual,
gestural, and spatial and then use new knowledge as they explain and predict phenomena (NGSS Lead States, 2013c; New London Group, 1996). This is done while frequently obtaining, evaluating and critiquing information from a variety of sources, both online and through teacher-provided resources. In organizing meaningful learning experiences for students to gain skills and knowledge of multiliteracies via scientific literacy through technologies, collaboration, and problem solving, teachers often voice barriers (Blackwell, Lauricella, Wartella, Robb, & Schomburg, 2013). These barriers are discussed in the following theme.

**Theme 3: A Modern Classroom for Science and Technology: Teaching and Learning in the Shadows of Time, Standards, and Testing**

This theme utilizes the term “modern classroom” in two ways. First, the modern classrooms of this study are wrought with a sense of increased accountability for teaching mandated standards, particularly for math and reading (Griffith & Scharmann, 2008; Goldston, 2005; Milner, et al., 2012). Because of this, Ms. Tyson and Ms. Randall find that time to teach science is a constant concern. The second use of “modern” refers to the increased integration of technology in society, specifically mobile devices and the Internet. Prensky (2001) argues that “Digital Immigrant teachers assume that learners are the same as they have always been, and that the same methods that worked for the teachers when they were students will work for the students now” (p. 4). Although both teachers admit that technology is becoming increasingly important in students’ lives, they each struggled in their own way with how to incorporate technology effectively in their science classrooms.

Students in both classrooms utilized technology in different ways on a daily basis. Some teacher-facilitated activities required the use of the Internet to research topics, while at other
times students took it upon themselves to quickly look up information without teacher guidance. As was noted earlier, multiple devices led to more student choice and engagement. Both teachers admitted that the Internet was indeed a quick, useful tool for this purpose. Although there was not a 1:1 ratio of students to mobile devices in either classroom (though the teachers wished each student had an iPad), students and teachers in both classrooms used laptops and mobile devices to personalize and individualize learning. Dexter, Dunleavy, and Heinecke (2007) outline the “added value” provided by multiple technologies including “an enhanced ability to find and retrieve relevant information via the web, an increased level of real-time formative assessment enabling individualized instruction, or the creation of virtual communities that allow students to communicate inside and outside of the classroom” (p. 441). Although the benefits of mobile devices were noted, struggles were identified as well. Issues of student accountability with online homework, grading, and access to technology were concerns that the teachers felt they still needed guidance with addressing. Simple logistics such as the time it takes to boot up a laptop and WiFi reliability were very real concerns as well. Both teachers, when asked what professional development they would like in the future, stated that they want to see what effective, efficient integration looks like in the classroom. Here lies an interesting tacit dissonance between the teachers’ views and students’ views. Although the teachers value technology integration, they struggle with the implementation and envisioning the big picture associated with multiliteracies. The students, on the other hand, were already on board and driving the ship without looking back.

Of course, classrooms do not exist in isolation from the larger educational community. National and local agendas, even with students’ well-being in mind, have the ability to support a school’s “normative, dominant, institutional cultural capital” (Robinson & Robinson, 2013). For
instance, given her prior experiences and personal learning preferences, Ms. Tyson repeatedly noted time and an overloaded curriculum as influencing how she taught science. Time and standards were voiced more frequently as a concern by Ms. Tyson than by Ms. Randall. In addition to time constraints, Ms. Tyson identified the breadth of standards that needed to be taught in a single year as an issue in science education. If she could teach science as she wished, she would teach fewer topics across the disciplines but spend more time to go deeper so her students would have a richer understanding of the content. Her words are reflective of the NGSS premise of “less is more” (NGSS Lead States, 2013i). In fact, the new standards do not have a lot of science standards required at each grade level. However, teachers may feel otherwise because of external pressures.

Although not stated explicitly in schools, it is inferred and common knowledge that teaching priorities (measured in time spent per subject) are placed on the tested subjects—reading and math. The national trends of decreased time spent on science in classrooms since the implementation of NCLB are publicly documented (Griffith & Scharmann, 2008; Milner, Sondergeld, Demir, Johnson, & Czerniak, 2012; Goldston, 2005). This is also supported by research which concludes that teachers are not only influenced by national and state policy, but by their local administration, as well (Milner et al., 2012). In the landscape of competing disciplinary priorities, at best science is a vestigial organ, at worst it has been excised from the curriculum bottom, so in essence it appears that science has been left behind (Goldston, 2005).

Teachers, evidently, are not the only stakeholders that recognize the influence of external factors (i.e. time and standards) on the modern classroom as restraints on teaching and learning science. Students are active participants in the same cultural and social realm as their teachers and are surprisingly astute about classroom interactions and their own learning (Fielding, 2004).
For instance, Roger, a fifth grader was asked if it would be useful for teachers to know student interests in science. He responded that it probably wouldn’t make a difference, though the NRC (2012) states that “personal interest, experience, and enthusiasm—critical to children’s learning of science at school or in other settings—may also be linked to later educational and career choices” (p. 12). Kevin didn’t think that his teacher even knew of his interests. Harold, when asked what type of science lesson he would plan responded that the class would read first, take an exam and get a grade, then do a project. The teaching and learning algorithm of reading first—testing—obtaining a grade, framed Harold’s enculturated view of the instructional sequence and has already shaped his expectations and he perpetuates what he has experienced. He placed investigative learning at the end of his list after accountability has already been met. Furthermore, he pondered the question suggesting that if everything they did was fun they would not learn as much because activities which were fun seem to take longer. Other students agreed, and one referenced learning in light of inquiry experiences saying, “You learn a little bit more (depth), but not as much (breadth).” This comment reflects Ms. Tyson’s desire to teach fewer standards more in-depth—learning more on fewer topics. The references to learning in a “fun” way may sound trivial on the surface, but the “fun” activities are anything but superficial. The “fun” activities described by students were hands-on, collaborative, thought provoking, memorable, and rich with science content and problem based, incorporating the elements of multiliteracies.

It is unclear whether both teachers have explicitly told students that there are too many standards and not enough time to teach through inquiry-based or problem solving approaches (though Ms. Tyson did explicitly say so in interviews), or if students are inferring such ideas from other cues they experience in school. In either case, the students held the same limitations
as their teacher described as factors that determine how and what science is taught. In fact, it appears they defend or rationalize the situation. This is not surprising, given that students are a part of the same school and testing culture as the teacher (Segool, Carlson, Goforth, Von der Embse, & Barterian, 2013). However, it is interesting that the students articulately addressed these issues, and in some cases were more creative and open to alternative ways of thinking about teaching and learning. Callie stated that if she was a teacher, she would let students “run wild” because then “you’re doing things. You’re still learning, but you’re doing it at your own pace and you’re finding things out by yourself.” Although several students believed the problem solving, student centered learning to be time consuming and even impractical for teachers due to time issues, other students, like Callie, imagined a science class where students do the hands-on work, and their voices are valued and heard despite the barriers of a test-driven educational climate.

With respect to collaboration, Ms. Randall viewed it as a necessity in meeting the Common Core standards, and though she advocated it, she worried that some students are not ready or mature enough to handle the responsibility associated with collaboration. Even with reservations, Ms. Randall viewed collaborative exercises as a teaching and learning tool where students were encouraged by their classmates through conversation in a way that promotes more in-depth science learning. Gee (2013) explains the importance of collaborative skills in his description of “affinity spaces” where a diverse group of people work together to solve a problem or achieve a common goal. In such a space, the whole is greater than the sum of its parts and the result is an optimal “learning space and democratic forum of the future” (Gee, 2013, p. 174). Although Ms. Tyson and Ms. Randall each struggled with some troublesome issues surrounding teaching science in the modern classroom, the future of students’ learning science
will rely heavily on teachers’ abilities to address, challenge, and overcome these issues (Collins & Halverson, 2009).

Because institutions are cultures, the roles, rules, discourse, expectations, and behaviors of teachers and students are defined within the culture, and those participating are enculturated into the ways of being, knowing, and doing within the culture. This is clearly seen in the words of the students who in a short few years have been enculturated into the schooling process. They know how teaching is carried out and defined, they know the expectations for learning and behaving in school in its variable contexts, and they even know that assessment drives what happens—so as one student pointed out, read about science, take the test, and when that is taken care of first, then we can enjoy learning science in meaningful ways. Within their roles as created and interpreted by teachers and students, there is a hierarchy of accountability that prioritizes what and how science is taught. Unfortunately, science and inquiry-based, student-centered approaches are designated a low priority in the hierarchy (Griffith & Scharmann, 2008; Milner, Sondergeld, Demir, Johnson, & Czerniak, 2012). Not surprisingly, the hierarchy with its time limitation sets the stage for the perpetuation of the traditional roles of the teacher as authority and students as passive receivers of knowledge. To break away from the status quo, creative use of time, multiliteracies, and shifts in the roles of teachers and students are needed to re-imagine a space for science learning that fosters students’ voice in the modern classroom. In doing so as stated by Goldston in an NSTA position statement (2014), teachers can “re-imagine the teaching of science for their future students and science for their students’ future.”

**Theme Four: Student Voices—Under Construction and Heard**
The modern science classroom with an emphasis on multiliteracies lends itself to epistemologies like constructivism that change the way one looks at how teachers teach and how students learn. This shift could alleviate the struggles that the teachers like those in this study expressed in their classrooms. Marenzi and Zerr (2012) assert that “the multiliteracies approach shares many ideas with the constructivist concepts of scaffolding and zone of proximal development where the basic idea is that cognitive development is directly linked to social development” (p. 337). Constructivism, as an epistemology, frames students as active constructors of knowledge (Fosnot, 1996). In this framework, each student uses unique prior experiences as they make meaning of their world. The result is a subjective construction of knowledge with each student forming their own unique view of the world. It comes from the notion that knowledge resides within the individual and not something outside the individual to be discovered. Given this context, constructivism and collaboration are a natural pairing that support each other. Within the scientific fields, collaboration is a way of life with teams of scientists often located in different countries working together to solve or unravel natural phenomena. So, in science classrooms it is logical and necessary that students are given opportunities to work in teams that allow them to construct knowledge with others. It is during such collaboration that students voice their knowings and misknowings, making it public for critique from team members and then re-construct, refine, and finally own it. Collaboration is paramount, as it gives students opportunities to give voice to thoughts and interact with as many varying perspectives and voices as possible as they construct their knowledge (Schweitzer & Stephenson, 2008). As a researcher and educator, placing value on the constructed voices of students provides an opportunity for growth and learning for both parties in ways we have yet to fully understand.
Student voice was evident in the data, not only in classroom experiences, but as a data source as well. As I conducted focus groups, there were three students between the two classes that I felt were pretending, disagreeing with the group just to stand out, or were being overly “silly.” However, the rest of the students were impressively engaged and willing to share their thoughts. These students were wise and sophisticated beyond their years with respect to the culture of schooling. At times, I was in awe, as I listened to one profound and thoughtful comment after another. The perceptiveness required to formulate many of their statements was as impressive as the statements themselves. For example, several students from Ms. Tyson’s class empathized with her concerns of time and standards limitations in science. Others displayed such intense metacognitive awareness and all but textbook-defined inquiry and constructivism in their descriptions of effective learning.

The previous section provided a discussion of major themes extrapolated from the findings in chapter four. Through science inquiry activities, visual literacy practices, collaborative exercises, and scientific practices, multiliteracies were enacted in ways that simultaneously supported and encouraged student voice and ownership of learning. However, there is much work yet to be done in preparing educators as they face the challenges of teaching in the modern classrooms within a rapidly evolving society. In the following section, conclusions will be drawn and implications for K-12 and teacher education will be presented.

Conclusions

A popular computer science concept, Moore’s Law, dictates that technology processing speed doubles every two years (Coffman & Odlyzko, 2002). In essence, every two years, computers are twice as fast as they were previously. Recently, it was also said that internet traffic
is doubling every two years as well (Coffman & Odlyzko, 2002). This exponential growth in technological advancement and use is contributing to an information revolution that affects every aspect of our society including economics, healthcare, communication, and education. The changes are not only occurring in society at large, but in our own minds. A recent study found that access to the Internet is changing the way in which people remember (or do not remember) information resulting in what is now known as the “Google Effect” (Sparrow, Liu, & Wegner, 2011). Essentially, if one knows that information is available online for later access, it does not necessarily need to be committed to memory, so it is not (Sparrow, Liu, & Wegner, 2011). In the world of education, the Google Effect has implications for the overall purpose and process of teaching and learning because if students know that fundamental content knowledge is available on the Internet, will they (should they) commit it to memory? If this finds its way into the culture of education, the result is redefining the purpose of education, shifting from content-centric to process-centric with an increasing emphasis placed on multiliteracies (Collins & Halverson, 2009; Knobel & Lankshear, 2009).

The rapid evolution of technology, automation, social media tools, and internet applications create a global connectedness that is quickly finding relevance in K-12 classrooms. Gee (2013) explains that “schools and colleges are focused on content…[and they] often stress this content rather than the activities that give rise to it” (p. 205). Innovations in technology, however, have created an information portal that makes the simple act of learning content all but irrelevant. According to Gee, “digital media now allows us to store, search, access, and represent this content in many different ways. Anyone can find the content at any time” (2013, p. 205). The multimodality of communication and information today, along with increasingly diverse and globalized societies, requires a new idea of literacy—multiliteracies. Current literature on
multiliteracies calls for an extension of research to be conducted in specific subject areas, such as done here, as well as an exploration of the impact of multiliteracies on students’ social and cultural selves (Ajayi, 2010; Moje, 2009). The recent development of the NGSS provides a relevant platform for exploring multiliteracies in science in conjunction with advances in technology. There have also been “major advances in science and our understanding of how students learn science” (NGSS Lead States, 2013j, para. 1). Furthermore, as multiliteracies and science education continue to evolve, student voices must be acknowledged in order to fully engage students and further their development of scientific literacy (Christidou, 2011).

In the previous section, the themes of this multiple case study were presented. Given the changing educational and societal climates that constantly influence students’ lives inside and outside the elementary classroom, multiliteracies are and will continue to play an important role in educating all students. The next section continues with conclusions drawn from the findings in chapter four as they pertain to the research questions of this study, then concludes with implications for changes in K-12 public education and teacher education.

**What and How are Multiliteracies, Science, and Scientific Practices Implemented in the Elementary Classroom?**

Multiliteracies were evident in the two classrooms through the implementation of instructional technology, mobile devices, visual literacy, problem solving, and distributed systems. Although utilized daily, multiliteracy experiences were developed in different ways and with varying degrees of teacher guidance. For example, both teachers led students through the analysis of diagrams and images in guided instruction, while at other times students used mobile devices (unprompted by their teacher) to look up pictures and information online in order to
Students interacted and communicated with all of the six multiliteracies design elements: visual, audio, spatial, gestural, multimodal, and linguistic (New London Group, 1996). Also, through varying levels of guidance, the teachers provided collaborative classroom climates that fostered distributed learning where students realized not only their peers’ strengths and weaknesses, but their own strengths and weaknesses as well. Multiliteracies were supported and developed through scientific practices which are essential to scientific literacy, a multiliteracy.

Through observations, it was discerned that all eight of the scientific practices outlined in the NGSS were observed between the two classrooms, though some were observed more than others (NGSS Lead States, 2013c). For example, “Using mathematical and computational thinking” was observed less frequently than “Obtaining, evaluating, and communicating information” (NGSS Lead States, 2013c). The scientific practices were primarily implemented through directed or guided inquiry, and were frequently used in conjunction with other instructional/learning resources such as text and computer programs.

**With Respect to Learning Science and Scientific Practices in the Classrooms of Study, How are Student Voices Engaged through Multiliteracies?**

While learning science, students were involved in investigations that utilized all of the scientific practices advocated by the NGSS (NGSS Lead States, 2013c). By the nature of the inquiry activities, students worked collaboratively utilizing multimedia tools to seek and analyze information. Through their interactions with multiple resources and their peers, particularly set within the context of collaboration, student voices emerged. As students interacted with technology, information, and communicated with each other during the science activities, their
level of questioning was heightened, and they reported feeling a sense of ownership of their learning. Furthermore, they held a clear self-awareness of their own learning.

In both classrooms, incorporating features of multiliteracies with scientific practices, such as student collaboration and discourse, created conditions conducive to developing student voice. Just as literacy is situated in practice (Olthouse, 2013), so too are collaborative practices within science. Olthouse (2013) argues that students “have a personal vision they wish to communicate, and a way of communicating that vision that is uniquely theirs” (p. 252). The collaborative activities demonstrated that scientific practices were effectively integrated within and supported with multimedia (e.g. videos, images, and text), technology applications (e.g. Science Court and the Internet), and real-world problems such as The Toothpick Bridge Project. Such opportunities created situations in which students had opportunities to share their voices as they engaged in meaningful conversations with each other. In what Navehebrahim (2011) coins a “new basic,” students must be able to effectively communicate in varying circumstances, “knowing that knowledge is increasingly created collaboratively, whether in work teams, through community development, or in scientific research laboratories” (p. 865). These collaborations, along with the use of other multiliteracies, assist in the students’ development of scientific literacy.

The convergence of multiliteracies (i.e. technology and visual literacy) with student voice was apparent in students’ perceptions. “Student voice as perspective,” or beliefs and opinions (Furman & Barton, 2006), was apparent through students’ ability to articulate how they make decisions online, evaluate websites, and how they perceive images on websites (Furman & Barton, 2006). “Student voice as participation,” or observable actions (Furman & Barton, 2006), was evident with activities where students were given choice and freedom in their learning experiences. Furman and Barton (2006) view voice as a “dynamic construct” in science which
ultimately reflects students’ learning. Learning in science, then, occurs “when students use their voices effectively to gain more scientific expertise, which will in turn allow them to increase their participation in science-related contexts” (Furman & Barton, 2006, p. 669). Students use of multiple devices in the classrooms of this study afforded them opportunities to research and evaluate online sources on a variety of topics, in a variety of ways, with or without explicit teacher direction. Students situated within contexts such as these have more freedom to decide how, when, and what they learn than those situated in traditional contexts. This contextual shift changes the dynamics of the learning process with students taking more ownership in the process and thus in what, and to what depth, their learning occurs.

Multiliteracies, or 21st century skills as referred to by Gee (2013), take on a variety of forms that include:

[The] ability to master new forms of complex and often technical language and thinking; ability to engage in collaborative work and collective intelligence where the group is smarter than the smartest person in it; creativity and innovation; ability to deal with complexity and to think about and solve problems with respect to complex systems; ability to find and marshal evidence and to revise arguments in the face of evidence; the ability to produce with digital media and other technologies and not just consume their content; and the ability to avoid being a victim of social forces and institutions that are creating a more competitive, stressful, and unequal world. (p. 202)

Juxtaposed to, the National Science Education Standards (NRC, 1996) say the following about scientific literacy:
Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately. (1996, p. 22)

However, given the changing social and technological climate, Weinstein (2006) asks the question, “To what extent is science education peddling a set of literacies no longer relevant to current practice, [and] are there science literacies we are not teaching students with our focus on inquiry as defined by NSES?” (p. 612). Weinstein speaks specifically to the reading and writing of science when he states that “in a scientific multiliteracy the often static, fact filled standard issue of text, is read alongside the literary products of these other scientific networks: magazines; science fiction; small scale videography; poetry; … and comics” (p. 618). Only then can students “learn to see the world through multiple perspectives” (p. 618) as is fundamental in the constructivist framework. Given the findings of this study, it is not just text, but the scientific practices of the NGSS when accompanied by multimodal interactions and students’ freedom of choice that are essential in providing experiences for students in which multiliteracies, or in this case scientific literacy, can develop. For example, the Toothpick Bridge Project in Ms. Tyson’s
class incorporated a variety of scientific and engineering practices while developing fundamental, yet complex, multiliteracies such as interpreting and producing sophisticated images and models, arguing with evidence, and utilizing multimodal resources. Though the students struggled at times, they were engaged in creative problem solving and productive argumentation with their peers. As Callie explained, without the struggle there would be no growth.

The learning opportunities observed in each elementary science class often fostered engagement in multiliteracies and the emergence of student voice. Within science, this was particularly salient when challenging students to evaluate online sources, an essential skill in the development of 21st century scientific literacy. These NSES skills include being able to “ask, find, or determine answers to questions derived from curiosity about everyday experiences, to be able to read with understanding articles about science in the popular press, and to engage in social conversation about the validity of the conclusions” (NRC, 1996). For example, in order to be scientifically literate, a citizen must be able to “pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately” (p. 22). Engagement with the NGSS scientific practice of “Engaging in Argument from Evidence” in Science Court (Scholastic, 2015) activities, students utilized multimedia (i.e. video and text) to collaborate with their group members, analyze information, and construct independent arguments based on evidence (NGSS Lead States, 2013c). These skills are imperative in fostering scientific literacy and multiliteracies.

It was clear in elementary science classrooms of this study that multiliteracies and scientific literacy are intertwined. More broadly, it is impossible to be scientifically literate in today’s society without proficiency in multiliteracies, though the development of multiliteracies
can occur without the use of scientific practices and knowledge of science content. Teacher and student perceptions of this literacy interdependence (multiliteracies and scientific literacy) support the notion that multiliteracies are supported and developed through problem-based, inquiry-based, science activities that utilized scientific practices.

**How Do Teachers and Students Perceive Multiliteracies, Student Voice, Science and Scientific Practices as they are Enacted in the Classroom?**

Though Ms. Randall and Ms. Tyson had not heard of “multiliteracies,” through their actions it was clear that they valued multiliteracies, student voice, and science. Given their very different teaching strategies and personal teaching philosophies, each one provided an atmosphere and experiences in their classrooms that supported multiliteracies. Though, neither teacher did this without some internal struggle. Ms. Tyson was bound by limited views of inquiry and multiliteracies, specifically effective technology implementation and cooperative learning, due to perceived barriers of time, standards, and student maturity. Ms. Randall was more open to inquiry and multiliteracies, though still aware of her own hesitations and limitations including classroom management and device management. Though each teacher shared concerns, they were open to the process of experimenting and trying new strategies in their science classrooms. Both teachers’ perceptions regarding student voices were similar in their beliefs that students’ perceptions were important and easily accommodated through varied learning activities. This gives the impression that teachers correlated voice with learning style, rather than the *sound* and *meaning* of students’ thoughts and ideas exposed for all to hear. The teachers did not mention the idea of creating environments that foster openness and the freedom to expose one’s thoughts to critique without fear of reprisal or suppression.
Ms. Tyson and Ms. Randall struggled with varying aspects of teaching in a “modern” classroom, which again can be characterized by increasingly technological while functioning within the constraints of local and national policy. Ms. Tyson, in particular, struggled with the notion of teaching science through inquiry due to time limitations, mandated standards, and developmental appropriateness associated with cooperative learning as barriers. The perception that inquiry requires too much time is a common concern among elementary teachers and it seems part of students’ thoughts as well. Other common apprehensions include classroom management concerns, teachers’ discomfort with content knowledge, teachers’ perceived concern over the difficulty inquiry poses for students, and a general misunderstanding of the nature of science in classrooms (Colburn, 2008; Goldston and Downey, 2013; Hodson, 1988; Welch, Klopfer, Aikenhead, & Robinson, 1981; Pomeroy, 1993; Slotta, 2004). Ms. Tyson had similar concerns in utilizing collaborative learning, an integral feature of teaching/learning through inquiry approaches, as well as a lack of student maturity with dealing with cooperative approaches. In an analysis of factors that impact teacher use of cooperative learning, Abrami, Pousen, and Chambers (2004) found that “expectancy of success” tended to be the most prominent factor in teachers’ willingness to implement cooperative learning. They argue that, similar to Ms. Tyson, “teachers need to believe they have both the skill to implement cooperative learning successfully and a context that is amenable to effective cooperative learning use” (Abrami, Pousen, & Chambers, 2004, p. 211). Therefore, teachers need to believe they can make it happen, and that it will work successfully with students.

With confidence in teaching through inquiry because of her AMSTI (2013) experiences (and resources), Ms. Randall admitted to feeling quite comfortable in a student-centered science classroom. Her concerns, however, dealt directly with logistical and management issues with
implementing technology. She was unsure of how to handle varying levels of internet access in students’ homes, online assessments, and managing multiple devices in the classroom. While already overwhelmed with limitations of “heavy set standardized assessments,” Jacobs (2013a) agrees that “implementing a pedagogy of multiliteracies…may be problematic,” particularly because “the technology is often foremost in teachers’ discourse rather than the thinking or creative processes engendered by the technology” (p. 625).

Though the teachers, through collaborative activities, enabled student voices to be heard with respect to content knowledge, there were student perceptions they never heard or elicited. There was a dissonance between student and teacher perceptions of multiliteracies, student voice, and scientific practices. Ms. Tyson, for example, shared that she believed her students enjoyed “popcorn reading” from their science textbook, whereas her students stated that they found reading the textbook boring and ineffective compared to other methods of learning. The students of this study were mature when sharing their perceptions and displayed impressive metacognitive awareness. It is common knowledge that effective teachers frequently search for and explore a variety of teaching strategies with the hopes of “reaching” their students. The students of this study were knowledgeable about what worked for them, and if given the chance could likely assist their teachers in creating a classroom environment that promotes student engagement and learning if only asked.

As the researcher, the students were open and eager to share their perceptions on multiliteracies, student voice, science, and scientific practices. Their metacognitive thinking was surprising and revealed itself in their awareness of their preferred ways to learn, as well as the importance of multiliteracies in their lives today and in the future. Furthermore, although most students explained that active learning was an enjoyable and effective way to learn science, two
students referred to lack of time and the breadth of standards as a barrier to incorporating such experiences in elementary classrooms. Students’ views in this case mirrored their teachers’ perceptions, particularly those of Ms. Tyson, who frequently stated time as a constant issue in teaching science. Given the findings and themes of this study, it is clear that there are issues that need attention. Thus, the current state of multiliteracies in science education with implications for teaching in K-12 and teacher education settings are presented next.

**Implications for Science Education**

The setting of the cases explored, Littleton Elementary in Morning City Schools, exists as both a strength and limitation of this study. Morning City Schools is traditionally one of the highest ranking school districts in the state (Niche.com Inc., 2015). Niche.com, for example, ranks Morning City Schools as the best school district in the state, taking into account the following weighted categories: 1) academic grade, 2) health and safety grade, 3) parent/student surveys of overall experience, 4) student culture and diversity grade, 5) teachers grade, 6) resources and facilities grade, 7) extracurricular and activities grade, and 8) sports and fitness grade (Niche.com Inc., 2015). Furthermore, Littleton Elementary was ranked by Niche.com as the 10th best public elementary school. Although diverse, standards are high, and resources are available to assist teachers and students in achieving their goals. Because of this, along with the Bring Your Own Device Policy, I expected to see multiliteracies in action. I assumed that students would frequently engage with technology in the classroom. I was right. This provided a unique environment in which to analyze multiliteracies and student voice in science. Because many of the students were already comfortable with the technological tools themselves, whether through years of practice at Littleton or through access at home, the use of technology in the classroom extended beyond simple technological and rote practices to more advanced and
purposeful practices. This is often observed in schools with students of high socioeconomic status (Warschauer, Knobel, & Stone, 2004).

While Littleton provided an environment rich with multiliteracies to study, it is clear that this was not a “typical” school. Although a Title I school, resources are abundant, students generally perform well on standardized tests (compared to other schools in the state), Stake (1995) suggests that although it is “useful to try to select cases which are typical or representative of other cases,” the ultimate goal “should be to maximize what we can learn” (p. 4). After all, “the real business of case study is particularization, not generalization” (Stake, 1994, p. 8). Even so, conducting the same study in alternative schools with different characteristics (e.g. fewer resources, lower socioeconomic status, higher percentage of minority students, urban, rural) may provide conditions for more “grand generalizations” (Stake, 1995, p. 7).

**K-12 Education**

When asked what kinds of professional development they would like to be a part of in the future, Ms. Randall and Ms. Tyson both stated that they would like to see the effective use of technology in elementary classrooms. Ms. Tyson shared,

I would love technology based professional development. [Learning] how to incorporate it and facilitate learning with it…That I can learn by myself. [I want to know how] to really use it in the classroom and apply it. When I was on the [electronic] textbook committee and we were being told about them, they pretty much said that you’re supposed to assign something and the students are supposed to teach themselves and figure it out. I would love to see how that works and see it applied in classrooms.
Ms. Randall made a similar statement,

[I want to see] probably just examples of teachers who are truly mastering integrating technology. [I want to see] real examples of what they do, how they manage it, how they use it, make sure you’re not over using it, make sure it’s used in the right way. Just hearing from other teachers would be nice.

Effective and purposeful professional development using and integrating a variety of current technologies for practicing teachers should be part of any modern classroom as the shift to technology-rich classrooms continues (Blackwell et al., 2013; Warschauer, Knobel, & Stone, 2004). Warschauer et al. (2004) provide three suggestions for facilitating meaningful technology use in schools: quality professional development and training are imperative; focus needs to be shifted from menial technological tasks to the broader learning experience; and access should be equal for all students (2004, p. 586). Blackwell et al. (2013) provide three recommendations for professional development with early childhood teachers, in particular. Professional development should be frequent, provide developmentally appropriate strategies and techniques, and encourage teachers to acknowledge the positive potential of technology in students’ lives (Blackwell et al., 2013).

Recently, a nonprofit initiative was established, “Leading the Digital Leap,” which is comprised of leaders from the Consortium for School Networking (CoSN), the National School Boards Association (NSBA), and the School Superintendents Association (AASA). A recent initiative highlights three important tenets that should be addressed when creating a digital or “tech-based” learning environment (Pierce, 2015, p. 2). The first two tenets, “Plan before purchasing” and “Replicate technology success,” speak directly to the needs and concerns
described by Ms. Tyson and Ms. Randall (Pierce, 2015, p. 2). Resolving logistical issues and providing professional development are integral components. The third tenet, however, speaks to a larger concern, “Usher in a culture of change” (Pierce, 2015, p. 2). Technology used to be something separate—it was an add-on, a luxury, or a novel way to teach/learn. In describing “new literacies,” Lankshear and Knobel (2006) view the world as being drastically different than it was in the past, requiring a new approach to literacy, whereas others believe that literacy is the same now as it always has been, just more “technologized” (p. 80). Although some educators still identify with a more primitive technological mindset, this is the not the societal reality.

As content becomes more readily available through technology, student collaboration and problem-solving have space to move to the forefront of educational goals. Jacobs (2013b) argues that “given the realities of today’s educational milieu, making multiliteracies work [in classrooms] involves a reconceptualization of schooling so that it incorporates fun, play, and the recognition that the result cannot and maybe should not be predicted” (p. 272). Gee (2013) imagines an educational system comprised of “interest-driven, passion-fueled… affinity spaces” where students work in fluid, flexible groups to solve problems or explore common interests (p. 174). He argues that these affinity spaces will be “the learning spaces and the democratic forums of the future” (Gee, 2013, p. 174). The defining characteristic of such a space is “synchronized intelligence” where each individual brings individual intelligence and diverse sets of skills “that make everyone smarter and make the space itself a form of emergent intelligence” (Gee, 2013, p. 174). However, there are eleven key features of affinity spaces:

1) Common endeavor, not race, class gender or disability, is primary,… 2) Newbies and masters and everyone else share common space,… 3) Some portals are strong generators,… 4) Internal grammar is transformed by external grammar,… 5) Encourages
intensive and extensive knowledge,… 6) Encourages individual and distributed knowledge,… 7) Encourages dispersed knowledge,… 8) Uses and honors tacit knowledge,… 9) Many different forms and routes to participation,… 10) Lots of different routes to status,… and 11) Leadership is porous and leaders are resources. (Gee, 225-228)

In short, this is synergy, “the sum is more than its parts; the collective is smarter than the smartest person in it” (Gee, 2013, p. 274). The students in this study clearly indicated that they found collaboration a preferred, effective and efficient method of learning.

Although the affinity spaces imagined by Gee (2013) are perhaps a bit theoretical and idealistic at this point in time, teachers are creating similar spaces within their classrooms with problem solving and project-based learning. Affinity spaces theoretically share many characteristics of project-based learning, defined as a “comprehensive instructional approach which engages students in an organized and cooperative manner to investigate and resolve a certain problem” (Musa, Mufti, Latiff, & Amin, 2011, p. 187). Project-based learning “engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic questions and carefully designed products and tasks” (Musa et al., 2011, p. 188). Project-based learning like the Toothpick Bridge Project, is constructivist in nature, and requires “spontaneity, collaboration, and flexible problem solving” (Hung, Hwang, Lee, Wu, Vogel, Milrad, & Johansson, 2014, p. 316). However, Gee (2009) argues that when comparing “the eleven features of an affinity group to most classrooms today, we usually find that the classroom either does not have a given feature or has it much more weakly than a prototypical affinity space” (p. 229). Students are typically segregated by grade level while they “are encouraged to gain pretty much the same knowledge across the board, knowledge which is often extensive and not intensive” (Gee, 2009, p. 230).
Moving further toward the vision of affinity spaces are more student-directed and flexible projects such as “20% Time” and “Genius Hour.” Influenced and inspired by a variety of forward-thinkers in education and other fields such as Pink (2009) and Maiers (2010), Genius Hour arose as a way to mirror Google’s 20% policy, in which employees are allowed 20% of their work time to develop any project of their liking (Kesler, 2015). In classrooms, Genius Hour is implemented in a variety of ways, including allowing students one day a week to pursue a passion project of their choice. Although not all students work on a collaborative project, they are encouraged to use all resources available including their peers and members of the community. Again, this contextual perspective embraces student freedom, fostering voice and ownership of learning and knowledge.

Changes are not only taking place at the micro, or classroom level, but they are changing at the macro level as well. Finland, a country known around the world for its excellence in public education, has recently proclaimed that their current educational system will undergo a major reform in the upcoming years. The national curriculum will be redesigned to implement a more “phenomenon-based” approach to teaching and learning which will “focus on transversal (generic) competencies and work across school subjects” (Halinen, 2015, para. 3). In a video by Irmeli Halinien, the Finnish National Board of Education’s head of curriculum development, it was explained that teaching specific, detail-oriented curricula is not useful for students anymore. She continued,

We are often asked, “Why improve the system that has been ranked as top quality?” The answer is, “Because the world is changing around the school.” We have to think and rethink everything connected to school. We also have to understand that competencies
needed in society and working life have changed and they are changing rapidly.

(Opetushallitus, 2014)

Interestingly, the Finnish system is placing increased responsibility on students as participants in planning and implementing the new problem-based, interdisciplinary learning experiences by requiring classrooms to implement time for students to “focus on studying phenomena or topics that are of special interest for students” (Halinen, 2015, para. 5). This was seen to some degree in the classrooms of this study. But by emphasizing the importance of student voice in the educational process—planning, experiencing, evaluating—the plan also hopes to increase student collaboration and meaningfulness of learning. The Finnish National Board of Education stated that “the core curriculum is based on the learning conception that positive emotional experiences, collaborative working and interaction as well as creative activity to enhance learning” (2015, para. 2).

**Teacher Education**

Teacher education programs in the United States, at this point, should be proactive instead of reactive. The elementary students in this study exhibited courage and creativity with respect to exploring and learning science with multiliteracies that should be mirrored by all educators. The students are “ahead of the curve,” so to speak with respect to how they should or how they would prefer to address their own learning, and their educators are reduced to playing catch-up instead of paving new multiliteracies pathways as part of their learning experiences. It should be a priority for practicing teachers to explore a more student-centered classroom through an awareness and use of multiliteracies giving rise to student voice, much like the teaching and learning described in the Finnish initiative. Interestingly, teacher education programs promote
integration of subjects in elementary classrooms, yet most program methods courses are still segregated by discipline areas. Teacher education programs should be on the forefront of educational change addressing research-based, innovative practices such as those associated with digital media and digital technologies. Instead, teacher education programs should at least be abreast of pedagogies for digital technologies and at best be a leader in reform efforts within the information revolution that is occurring in society and in classrooms.

In November of 2010, the National Council for Accreditation of Teacher Education (NCATE) released the “Report of the Blue Ribbon Panel on Clinical Preparation and Partnerships for Improved Student Learning.” Technology integration is embedded throughout the report both directly and indirectly, as is to be expected in today’s educational realm. Pre-service teachers should be well-versed in not only how to implement current and evolving technology in the classroom, but also know how to seek funding and professional development throughout their career as technologies continue to grow and change. Technology plays a particularly important role in science education, and should be incorporated into science methods courses at all levels, as part of STEM initiatives. Similar to inquiry-based teaching, effective technology-based teaching is not tool-specific, but rather a collection of skills that can be applied to a variety of circumstances. Because technology resources vary from school to school, teacher education programs must lead the way in preparing pre-service teachers to “creatively adapt and evolve when using technology” (Wright & Wilson, 2011, p. 58). In order to do this, university instructors must develop and participate in professional development on the instructional uses of multiliteracies, particularly digital technologies, with the intent of modeling effective technology integration in their courses.
Science in teacher education requires specific attention to several essential characteristics for successful programs, including an emphasis on the value of inquiry-based and cooperative team teaching. Furthermore, pre-service teachers must have opportunities to observe and practice teaching through inquiry and cooperative learning in a variety of environments. Current research suggests several methods for preparing pre-service teachers for inquiry teaching in science, including modeling inquiry-based instruction and giving pre-service teachers the chance to develop and implement their new strategies in a variety of classrooms (Avery & Meyer, 2012). However, because many pre-service teachers may have never experienced inquiry-based methods or scientific practices as students (in K-12 education or in university courses), it is important to nurture novice teachers in these practices (Avery & Meyer, 2012). Similar to acquainting elementary students with inquiry, it is suggested that pre-service teachers be eased into the process first through directed inquiry then guided inquiry, modeled and facilitated by the instructor, and then gradually exposed to more open or full inquiry (Avery & Meyer, 2012; Gabel, 2006). Thus, not only are pre-service teachers exposed to the methods in which science should be taught in elementary school, but they are also experiencing first-hand the benefits of learning through inquiry (Varma, Volkmann & Hanuscin, 2009).

Learning and teaching through inquiry are two distinct actions. Therefore, it is imperative that pre-service teachers are given opportunities to practice these skills with students. NCATE (2010) describes ten design principles that are suggested as foci for a clinically based program, all of which have implications for science in teacher education. These include:

1) Student learning is the focus, 2) Clinical preparation is integrated throughout every facet of teacher education in a dynamic way, 3) A candidate’s progress and the elements of a preparation program are continuously judged on the basis of data, 4) Programs
prepare teachers who are expert in content and how to teach it and are also innovators, collaborators, and problem solvers, 5) Candidates learn in an interactive professional community, 6) Clinical educators and coaches are rigorously selected and prepared and drawn from both higher education and the P-12 sector, 7) Specific sites are designated and funded to support embedded clinical preparation, 8) Technology applications foster high-impact preparation, 9) A powerful R&D agenda and systematic gathering and use of data supports continuous improvement in teacher preparation, 10) Strategic partnerships are imperative for powerful clinical preparation. (NCATE, 2010, p. 5-6)

The overarching position of the document is that clinical fieldwork is an integral part of teacher education programs, and should therefore be a top priority. Darling-Hammond (2010) describes this as “learning about and from practice in practice,” a process that can only be achieved through successful partnerships between universities and local schools (p. 42). Because teaching through inquiry often requires a conceptual shift for many pre-service teachers, having a chance to observe the use of inquiry in K-12 classrooms is critical. However, pre-service or novice teachers cannot be thrust into elementary classrooms and be expected to teach with inquiry and cooperative learning, essential elements of multiliteracies, for extended periods of time with full confidence. Therefore, effective clinical experiences under expert guidance should gradually allow pre-service teachers to observe and then practice such skills as opportunities grow in frequency and complexity (Wagler, 2011).

As part of multiliteracies, constant innovations in digital technology, as well as other technologies, impact almost every aspect of daily life, big and small. Society is globally connected while at the same time more locally diverse (Cope & Kalantzis, 2000). This has special implications for multiliteracies and teacher education programs as they prepare teachers
to meet the needs of a diverse population. Preparing teachers to work with diverse populations in teacher education is salient and must be addressed both generally and in the content areas. In a study of over three hundred science and math lessons, Weiss et al. (2003) noted that there is a “pattern of differential quality of instruction across types of communities, in classes with varying proportions of minority students, and in classes of varying ability levels” (p. 104). Overall, lessons observed in rural classrooms and classrooms with a high number of minority or “low ability” students were of lesser quality than other classrooms (Weis et al., 2003, p. 104). Not to be mistaken with inquiry-based lessons, in this study traditional lessons could be rated as “high quality” as well. Unfortunately, many students are receiving less than adequate science instruction, despite the delivery method. So, teacher education should be “developing teacher capacity to succeed with every pupil, especially those historically under-served and those with special learning needs” (Williamson, McDiarmid, & Clevenger-Bright, 2008, p. 148).

In closing, teacher education programs should be guided by the works of Ladson-Billings who asserts that teacher education programs have not recruited a diverse enough population of scholars because “scholars of color are expected to […] focus solely on topics of diversity” (2011, p. 14). Currently, “teacher educators typically teach White middle-class teacher candidates who are able to learn successfully in conventional ways but lack experience with teaching the diverse population found in today’s schools and classrooms” (Jenlink, 2005, p. 7). Therefore, an emphasis needs to be placed not only on the recruitment of a diverse population in the faculty, but in the population of pre-service teachers as well.
Summary

As student access to information and the world around them continues to evolve, so too must educational practices. The primary emphasis in science, traditionally being placed on content, must shift to an emphasis on process, practices, and real-world applications. With students’ instinctively creative and innovative dispositions, the challenge will not be to convince them to explore science in a new way—they are ready. The real challenge lies in encouraging teachers, administrators, and policy-makers to envision a new system of education where content is one goal, but not the primary goal. The primary goal is to inspire a passion for learning, solving problems, and asking questions. In the quest to learn, problem solve, and answer questions students will have to interact with a vast array of resources including their peers, technological tools, community members, and the natural world. The findings from this study indicate that as we search for ways to move forward in this process of rethinking the purpose of education, students may be our most valuable resource. Perhaps, it is time to let them teach us.
REFERENCES


APPENDICES

Appendix A

January 14, 2014

Elizabeth Allison
Department of Curriculum & Instruction
College of Education
Box 870232


Dear Ms. Allison:

The University of Alabama Institutional Review Board has granted approval for your proposed research.

Your application has been given expedited approval according to 45 CFR part 46. Approval has been given under expedited review category 7 as outlined below:

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies

Your application will expire on January 13, 2015. If your research will continue beyond this date, complete the relevant portions of the IRB Renewal Application. If you wish to modify the application, complete the Modification of an Approved Protocol Form. Changes in this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants. When the study closes, complete the appropriate portions of the IRB Request for Study Closure Form.

Please use reproductions of the IRB approved stamped consent/assent forms to obtain consent from your participants.

Should you need to submit any further correspondence regarding this proposal, please include the above application number.

Good luck with your research.

Sincerely,

[Name Redacted]

Director & Research Compliance Officer
Office of Research Compliance
The University of Alabama
Appendix B

INFORMED CONSENT FOR TEACHERS

Exploring Multiliteracies, Student Voice, and Scientific Practices in Elementary Classrooms

Elizabeth Allison, PhD Student

You are being asked to take part in a research study. This study is called “Exploring Multiliteracies, Student Voice, and Scientific Practices in Elementary Classrooms.” The study is being done by Elizabeth Allison, who is a PhD student at the University of Alabama. Mrs. Allison is being supervised by Dr. Marion “Dee” Goldston who is a professor of science education at the University of Alabama.

This study is being done to find out what tools (books, computers, etc.) are being used in elementary classrooms to teach science, and how those tools influence student engagement, participation, and learning. This knowledge is important because it will help us understand what students feel about different teaching strategies and learning opportunities in science classrooms. You have been asked to participate in this study because you are an upper-elementary teacher, and you stated through email and in meetings that you teach science on a regular basis in your classroom.

Two teachers and their students (approximately 50 children) will participate in this study. I will observe in each classroom up to three hours a week. If you agree to participate in this study you will also be asked to take part in interviews (approximately one hour) up to once a month. Interviews will be audio- and video-recorded. Observations will occur up to three days a week over the course of five months, totaling approximately 60 observation hours in your classroom with up to five hours of interviews—65 total hours.

Students in your classroom, if they agree to take part in this study, may be asked to do the following:

- **Participate in focus groups.** After a science activity, I may ask your students to answer some questions about what they did in the activity and how they felt about it. The focus group will be audio- and video-recorded.

- **Participate in individual interviews.** I may ask a student questions about learning science, tools used in the classroom, and/or how they feel about learning science in their classroom. Interviews will be audio- and video-recorded.

Focus groups will only last approximately 15 minutes. Up to three individual interviews with students may be conducted (15 minutes/interview) totaling up to 45 minutes. The entire study will take less than two hours of students’ time over the course of five months. The only cost to you for this study is time.
There are no foreseeable risks for this study. Although you will not benefit personally from being in the study, you may feel good knowing that you have helped teachers understand students’ feelings about learning science. This study will help educators to understand learning science from elementary students’ perspectives.

Your privacy will be protected in several ways. Interviews will be done in a quiet, private area (your classroom after school, for example). You will not have to answer any questions if you do not want to. Confidentiality will be protected by using pseudonyms in any reports or presentations. Signed informed consent and assent forms will be kept in a locked file cabinet for up to five years and then destroyed. Audio and video recordings will be promptly transferred to digital copies on a password protected computer and then the original files will be deleted. Only one person will have access to the digital files.

The alternative to this study is to not participate. Taking part in this study is voluntary. It is your free choice. You can refuse to participate at all. If you start the study, they can stop at any time. There will be no effect on your relationship with the University of Alabama.

The University of Alabama Institutional Review Board ("the IRB") is the committee that protects the rights of people in research studies. The IRB may review study records from time to time to be sure that people in research studies are being treated fairly and that the study is being carried out as planned.

If you have any questions, concerns, or complaints about the study right now, please ask them. If you have questions, concerns, or complaints about the study later on, please call the investigator, Elizabeth Allison, at (205) 401-9001. You may also contact Dr. Dee Goldston at 205-348-0923. If you have any questions about your rights as a person in a research study, call Ms. Tanta Myles, the Research Compliance Officer of the University, at 205-348-8461 or toll-free at 1-877-820-3066.

You may also ask questions, make suggestions, or file complaints and concerns through the IRB Outreach website at http://osp.ua.edu/site/PRCO_Welcome.html or email the Research Compliance office at participantoutreach@bama.ua.edu.

After you participate, you are encouraged to complete the survey for research participants that is online at the outreach website or you may ask the investigator for a copy of it and mail it to the University Office for Research Compliance, Box 870127, 358 Rose Administration Building, Tuscaloosa, AL 35487-0127.

I have read this consent form. I have had a chance to ask questions. I agree to take part in it. I will receive a copy of this consent form to keep.

_________________________________________________________________
Signature of Research Participant      Date

_________________________________________________________________
Signature of Investigator       Date
Appendix C

PARENTAL PERMISSION FORM

Exploring Multiliteracies, Student Voice, and Scientific Practices in Elementary Classrooms

Elizabeth Allison, PhD Student

Dear Parent/Guardian,

You are being asked to give permission for your child for whom you are a guardian/legal representative to take part in a research study. This study is called “Exploring Multiliteracies, Student Voice, and Scientific Practices in Elementary Classrooms.” The study is being done by Elizabeth Allison, who is a PhD student at the University of Alabama. Mrs. Allison is being supervised by Dr. Marion “Dee” Goldston who is a professor of science education at the University of Alabama.

This study is being done to find out what tools (books, computers, etc.) are being used in elementary classrooms to teach science, and how those tools influence student engagement, participation, and learning. This knowledge is important because it will help us understand what students feel about different teaching strategies and learning opportunities in science classrooms.

Two teachers and their students (approximately 50 children) will participate in this study. I will observe in each classroom up to three hours a week. If your child agrees to participate in this study, he/she may be asked to do these things:

- **Participate in focus groups.** After a science activity, I may ask your child (along with other classmates) to answer some questions about what they did in the activity and how they felt about it. The focus group will be audio- and video-recorded.

- **Participate in individual interviews.** I may ask your child questions about learning science, tools used in the classroom, and/or how they feel about learning science in their classroom. Interviews will be audio- and video-recorded.

Focus groups will only last approximately 15 minutes. Up to three individual interviews may be conducted (15 minutes/interview) totaling up to 45 minutes. The entire study will take less than two hours of time over the course of five months. The only cost to your child for this study is time.

There are no foreseeable risks for this study. Although your child will not benefit personally from being in the study, they may feel good knowing that they have helped teachers understand students’ feelings about learning science. This study will help educators to understand learning science from elementary students’ perspectives.

Your child’s privacy will be protected in several ways. Focus groups and interviews will be done in a quiet, private area (the library, for example). They will not have to answer any questions if they do not want to. Confidentiality will be protected by using pseudonyms in any reports or presentations. Signed parental permission forms and assent forms will be kept in a locked file...
cabinet for up to five years and then destroyed. Audio and video recordings will be promptly transferred to digital copies on a password protected computer and then the original files will be deleted. Only one person will have access to the digital files. Confidentiality cannot be guaranteed during the focus groups because multiple students will be having a discussion, but I will ask the students to keep the discussion private.

The alternative to this study is to not participate. Taking part in this study is voluntary. It is your free choice. You can refuse to allow your child to participate at all. If they start the study, they can stop at any time. There will be no effect on their relationship with their teacher, class, or the University of Alabama.

The University of Alabama Institutional Review Board ("the IRB") is the committee that protects the rights of people in research studies. The IRB may review study records from time to time to be sure that people in research studies are being treated fairly and that the study is being carried out as planned.

If you have any questions, concerns, or complaints about the study right now, please ask them. If you have questions, concerns, or complaints about the study alter on, please call the investigator, Elizabeth Allison, at (205) 401-9001. You may also contact Dr. Dee Goldston at 205-348-0923. If you have any questions about your rights as a person in a research study, call Ms. Tanta Myles, the Research Compliance Officer of the University, at 205-348-8461 or toll-free at 1-877-820-3066.

You may also ask questions, make suggestions, or file complaints and concerns through the IRB Outreach website at http://osp.ua.edu/site/PRCO_Welcome.html or email the Research Compliance office at participantoutreach@bama.ua.edu.

After you participate, you are encouraged to complete the survey for research participants that is online at the outreach website or you may ask the investigator for a copy of it and mail it to the University Office for Research Compliance, Box 870127, 358 Rose Administration Building, Tuscaloosa, AL 35487-0127.

I have read this consent form. I have had a chance to ask questions. I agree to take part in it. I will receive a copy of this consent form to keep.

Thank you very much for your interest.

Sincerely,

Elizabeth Allison
Investigator
☐ I agree to let my child participate in this study.

Please check the boxes that apply.

☐ I agree to let my child to be audio-recorded during focus groups and/or interviews.

☐ I agree to let my child to be video-recorded during focus groups and/or interviews.

☐ I do not want my child to be audio or video recorded.

Please check one box.

☐ Data from this study involving my child can be used in research presentations.

☐ I do not want data from this study involving my child to be used in research presentations. Instead, it should only be used for this study alone.

☐ I do not want my child to participate in this study.

_____________________________  ____________________________
Signature of Research Participant’s Parent/Guardian    Date

_____________________________  ____________________________
Signature of Investigator       Date
Appendix D

ASSENT FORM

Dear Student,

I am from the University of Alabama and I am doing a study on science and literacy in elementary classrooms. I would like to know how science is taught, what tools are used to teach science, and how students communicate during science class. This study will help teachers understand what children your age think about learning science.

Your teacher and one other teacher have agreed to participate in this study. I will be coming to your classroom up to three times a week to observe during your science time. I am also asking all of the students in both classes to be in this study. If you decide to be in the study, you may be asked to take part in a focus group one day where I would ask you and some classmates about an activity you have done in science class. I may also ask to speak to you individually about what you think about science class. Interviews and focus groups would only last about fifteen minutes.

I will tape-record and vide-record the focus groups and interviews so that I will have a good record of our conversations. I will type up what is said during the meetings, but no names will be used. The tapes will be kept on a password protected computer. If you do not want to be in a tape-recorded or vide-recorded discussion, you should not be in this study.

I will not tell anyone outside of the study what you or any of your classmates have said. I will write a report on the study that talks about what I saw in the classroom and what you and your classmates share in focus groups and interviews. I will also give presentations about this study where I may use short video clips from our meetings, but I will never share your name or what school you are from. I will ask kids in the groups not to talk about what was said in our meetings (to keep the discussion confidential), but I cannot promise this. You can control this by not saying something you would not want to have repeated. I will not tell your parents or teachers what you said.

You are a volunteer. You are helping me but you do not have to unless you want to. This is your free choice. If you start the study and decide you don’t want to continue, just let me know. No one will be mad at you. If you do not want to talk about a certain topic in our conversations or answer a certain question, you do not have to.

I do not think there are any risks or harm to you in this study. You might find the discussions helpful to you or it may make you feel good to know you are helping us understand how science is taught and what students think about it.

If you have any questions about this study, please ask me now. If you have any questions later, you can ask me anytime. You can also ask your parents if you want. If you have any questions about your risks in a research study, please contact Ms. Tanta Myles, the University of Alabama Research Compliance Officer, at (205) 348-8461.
If you agree to be in this study, please sign your name on this letter below. I will give you a copy of this letter to keep.

Thank you very much for your interest.

Sincerely,

Elizabeth Allison
Investigator

Please check all boxes that apply.

☑️ I do not want to be audio-recorded during focus groups and/or interviews.
☑️ I do not want to be video-recorded during focus groups and/or interviews.

________________________________________________________    _________
Name of Participant         Date

________________________________________________________    _________
Person Obtaining Assent      Date
Appendix E

Observation Protocol

1. What tools are being used by the teacher? By the students?
2. How are the tools being used?
3. How are the students interacting with each other? With the teacher?
4. How is language being used?
5. What science concept is being explored?
6. What scientific and/or engineering practices are being used?
Appendix F

Teacher Interview Protocol #1 (Ms. Randall and Ms. Tyson)

1. Tell me about your education and teaching experiences.

2. What does a typical science lesson look like in your room?

3. When students leave your class at the end of the year, what do you expect them to be able to “do” in science?

4. How do you go about planning science lessons?

5. What resources do you use to plan science lessons?

6. What types of technology do you and your students have access to?

7. What role does technology play in your classroom?

8. Do you think technology affects student learning in science? Why or why not? How so?

9. What is the students’ role in your classroom?

10. If you were to imagine your students in twenty years, what do you think they need to be able to do (what skills should they have) that will make them successful?

11. How do you, as a teacher support these skills?

12. How do you inhibit these skills?
Ms. Tyson Interview Protocol #2

1. Thinking back to when you were in school, what was your experience like in science?
2. Why do you think you teach the way you do?
3. What do you find exciting about teaching?
4. What does “educating the whole child” mean to you?
5. How do you perceive the importance of students’ interests when teaching science?
6. What do your students enjoy the most about learning science?
7. How comfortable are you with teaching science content?
8. Do you plan with the grade level?
9. What are the benefits of using the iPads for research?
10. What about Science Court as a computer program?

Ms. Tyson Interview Protocol #3

1. Tell me about the Toothpick Bridge Project. What did the students learn (content/skills)?
2. What do you think classrooms of the future will look like? What will the students be doing?
3. If you be a part of any professional development activity, what would like to learn more about?
4. What kinds of activities do you incorporate that help you to learn the most about your students?
Ms. Randall Interview Protocol #2

1. Thinking back to when you were in school, what was your experience like in science?
2. Why do you think you teach the way you do?
3. What do you find exciting about teaching?
4. What does “educating the whole child” mean to you?
5. How do you perceive the importance of students’ interests when teaching science?
6. What do your students enjoy the most about learning science?
7. How comfortable are you with teaching science content?
8. What are the benefits of using the websites with images (otter)?
9. Talk about the adaptations project. How did you go about planning? What strategies are you using?

Ms. Randall Interview Protocol #3

1. Tell me about how your class is using Skype tomorrow.
2. How do you think using different tools like Skype affects student learning?
3. What kinds of activities do you incorporate that help you to learn the most about your students?
4. What do you think classrooms of the future will look like? What will the students be doing?
5. If you be a part of any professional development activity, what would like to learn more about?
Appendix G

FOCUS GROUP PROTOCOLS—MS. RANDALL’S CLASS

Focus Group Protocol #1

1. Tell me about Schoology.
2. Tell me about the light bulb activity you did yesterday. What did you do? What did you learn?
3. You had to write about the circuit and draw a picture. What is the difference between the two?
4. If you could change one thing about the activity, what would you change?

Focus Group Protocol #2

1. Tell me about the comic strips you used in science the other day.
2. When you were learning about classifications, you each chose an animal to research. Tell me about your animal, why you chose it, and how you researched it.
3. Tell me about the animal websites you looked at as a class.
4. When do you have/ask the most questions in science class?
5. Tell me about working by yourself and working with your classmates.
6. If you were a fourth grade science teacher and you could plan and teach any science lesson, what would you do?

Focus Group Protocol #3

1. Tell me about the comic strips you used in science the other day.
2. When you were learning about classifications, you each chose an animal to research. Tell me about your animal, why you chose it, and how you researched it.
3. Tell me about the animal websites you looked at as a class.
4. What do you think about looking things up online?
5. Tell me about how you use Google Docs and Schoology in class.

Focus Group Protocol #4
1. Tell me about being able to choose your topic when you’re working on a project in science.
2. Tell me about your adaptations project—researching, drawing, and labeling your animal.
3. What is your favorite thing you have done in science?
7. If you were a fourth grade science teacher and you could plan and teach any science lesson, what would you do?
Appendix H

FOCUS GROUP PROTOCOLS- MS. TYON’S CLASS

Focus Group Protocol #1

1. What do you think about working in groups in science versus working alone?
2. When you research on the internet, how do you decide which websites to use?
3. How do you decide what information to write down?
4. What do you think about your textbook?
5. How is looking at pictures and diagrams different than reading?
6. What do you think about BrainPop?
7. If you were given a camera, do you think you could make a video like BrainPop?
8. If you could teach a science lesson, what would you do?
9. What do you think is your job in the classroom?

Focus Group Protocol #2

1. You’ve been doing a lot on the iPad. How does that compare to the textbook?
2. On Monday your teacher gave you a question to research. How did you go about finding the answer?
3. What websites do you use?
4. What was the diagram on your quiz yesterday?
5. If you could teach a science lesson, what kinds of tools would you use?

Focus Group Protocol #3

1. Tell me about Science Court.
2. What science skills are you learning through Science Court?
3. How would you, or did you, use your tablet at all with Science Court?
4. Tell me about working in groups versus working independently.
5. If you could design a science lesson, what would you do?
Focus Group Protocol #4

1. You just finished Science Court. What did you think about that program?
2. Yesterday, you began researching some elements on the periodic table with iPads and laptops. Tell me about what you’re doing.
3. Do you like being able to choose the elements?
4. Can you think of other ways to use QR codes in science?
5. If you were to plan any science lesson, what would you do?
6. Do you think your teacher knows what you’re interested in when learning science?

Focus Group Protocol #5

1. How do you think using the Internet helps you learn in science?
2. Have you ever used Google Drive in science?
3. How do you use technology?
4. If you were a teacher and could plan any lesson, what kind of science lesson would you plan?
Appendix I

Callie Interview Protocol #1

1. When you hear the term “student voice” what do you think it means?

2. How do you think technology affects what you do in science class?

3. Tell me about working with your classmates versus working independently.

4. What is your favorite way to learn?

5. Tell me about videos and pictures in science.

6. When do you have questions in science?

Callie Interview Protocol #2

1. Tell me about the Toothpick Bridge Project.

2. What is the difference in doing something like the Toothpick Bridge Project and reading, like you did with matter and elements?

3. What has been the biggest struggle with the project?

Callie Interview Protocol #3

1. What have you learned from the toothpick bridge project?

2. If I gave each student in your class a laptop/iPad, how would you use them to teach science?

3. How could you use them to communicate with other people?
4. How would it change your student voice?

5. If you could give advice to teachers about teaching science, what would you tell them? (technology, student choice, engagement, etc.)

Kevin Interview Protocol #1

1. What do you enjoy most about learning science?

2. How much input do you think you have when it comes to the way you learn science?

3. Can you think of a time when you had choices in science?

4. Lately, you have been using an iPad in science to research different things. What do you think about using the iPad and laptops in science?

5. Do you think technology makes a difference in how you communicate and participate in class?

6. You said you were an auditory learner. What does that mean to you? How do you know that?
Kevin Interview Protocol #2

1. What in science class makes you wonder?

2. Yesterday, you asked if she peeled the lemon if it would sink. How did you feel when she actually tried it?

3. What two jobs did you apply for in the Toothpick Bridge Project? Why?

4. Tell me about collaborating with your classmates.

Kevin Interview Protocol #3

1. Tell me about the Toothpick Bridge Project.

2. If each student in your class had an iPad, how do you think you could use them in science?

3. If you could give advice to teachers about teaching science, what would you tell them? (technology, student choice, engagement, etc.)
Appendix J

Aaron Interview Protocol #1

1. What has been your favorite thing you have done in science this year?
2. Tell me about writing and drawing in science.
3. Tell me about your animal adaptations project. What did you chose? How did you research it?
4. What did you think about using the comic strips?

Aaron Interview Protocol #2

1. What is your favorite way to learn in science?
2. Tell me about working with other people versus working by yourself.
3. How do you think your teacher knows what science things you’re interested in?
4. How does your teacher learn about you?

Gabriella Interview Protocol #1

1. What has been your favorite thing you’ve done in science this year?
2. Tell me about your animal adaptations project. What did you chose? How did you research it?
3. What do you think about the animal websites you looked at in class?
4. If you could learn about anything in science, what would you learn about?

Gabriella Interview Protocol #2
1. Yesterday, you had your friend draw your picture in science. Why did you do that?

2. How do you think your teacher learns about you?

3. Tell me about the metamorphosis game you played the other day.

4. If you could give advice to teachers, what advice would you give?
Appendix K

BUILDING BRIDGES OF TEAMWORK
Littleton Elementary 5th Grade Toothpick Bridge Construction Project
Sponsored by Dixon Architects, Inc.
March 28, 2013

Everyone get ready for a fun and exciting collaborative toothpick building project! To wrap up our great year in math, each classroom will break into small teams to form a company that will work together over the next several weeks to design and construct a toothpick bridge. Each company will be responsible for managing their project budget and project schedule, while developing an innovative design solution that is constructed with craftsmanship, and finally marketed to tell the story of what makes their work so special. The project concludes with an exciting morning of judging and testing to evaluate how the bridges perform under pressure.

COMPANY AND INDIVIDUAL DUTIES

Project Director:

• Maintains project schedule, makes sure all company members do their jobs
• Keeps daily journal of company’s progress, recording any problems and their solution
• Signs and approves building plans, checks and order forms
• Makes sure construction site is neat and organized
• Cleans up site and stores bridge each day
• Responsible for maintaining company records

Architect:

• Designs bridge draws plans
• Shows others how to construct bridge according to the plans
• Keeps inventory of building materials on hand at site
• Makes sure actual bridge being built follows and looks like the plans
• Orders supplies, filling out order form as needed

Carpenter:

• Builds bridge according to architect’s plans
• Consults with architect as bridge construction proceeds
• Supervises company members who help with construction (transportation chief and accountant)

Transportation Chief:
• Helps carpenter build the bridge
• Delivers checks, picks up supplies from the warehouse (only company member who does business with the warehouse)

Accountant:
• Writes checks to go with order forms
• Keeps balance sheet current each day and makes sure that company account is accurate
• Meets with auditor if necessary
• Helps carpenter build the bridge

Marketing (all company members):
• Team agrees on company name and logo
• Team chooses local charity for donation of any monetary awards received
• Team identifies qualities that make their project special for sign poster presentation
• Team assembles company sign with project facts and important considerations

**BRIDGE BUILDING CODE**
• The bridge plans shall show four views: the view from one end, the side view, the road bed, and the top view. The plans must be readable, clear, scaled, and may not be changed once construction begins
• The bridge will be constructed on land to be purchased from the warehouse
• The bridge must at all times touch only the land inside the black squares
• The bridge must span 15cm wide over the river denoted on the land
• The bridge must be at least 5cm high to allow for the official boat to pass down the river
• The bridge must be at least 4cm wide to allow for the official truck to pass the length of the roadbed
WAREHOUSE MATERIALS PRICE LIST

- BEGINNING BALANCE…………………………….……$1,550,000
- Land (pre-cut foam board)……………………………………$500,000
- Lumber (toothpicks)…………………………………………...$10,000 per piece
- Cable (string)…………………………………..………………….$500 per cm
- Welding material (glue)……………………………………..…….$850 per day
- Building plans and paper (graph paper & wax paper)……….$40,000
- Extra sheets of either paper………………………………..…..$10,000
- Audit Service (one required minimum)………………………….$2,000

BRIDGE TESTING DAY

- Testing day is scheduled for the morning of Thursday, May 2\textsuperscript{nd}
- All bridges will be displayed with company signage
- Ribbons will be displayed for top three Most Creative bridges
- Classes will be grouped and tested for qualifying weight, then finalists will compete together

AWARDS CEREMONY

- Most Creative Bridge- as determined by an esteemed panel of judges
  o $100 donation to team charity
- Strongest Bridge- supports the most weight
  o $200 donation to team charity
- T-shirts for all participants!