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Investigating Engagement, Thinking, and Learning Among Culturally Diverse,
Urban Sixth Graders Experiencing an Inquiry-Based Science Curriculum,
Contextualized in the Local Environment

by

Sybil Schantz Kelley

A dissertation submitted in partial fulfillment of the
requirements for the degree of

Doctor of Philosophy
in
Environmental Sciences and Resources

Dissertation Committee:
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ABSTRACT

This mixed-methods study combined pragmatism, sociocultural perspectives, and systems thinking concepts to investigate students' engagement, thinking, and learning in science in an urban, K-8 arts, science, and technology magnet school. A grant-funded school-university partnership supported the implementation of an inquiry-based science curriculum, contextualized in the local environment through field experiences. The researcher worked as co-teacher of 3 sixth-grade science classes and was deeply involved in the daily routines of the school.

The purposes of the study were to build a deeper understanding of the complex interactions that take place in an urban science classroom, including challenges related to implementing culturally-relevant instruction; and to offer insight into the role educational systems play in supporting teaching and learning. The central hypothesis was that connecting learning to meaningful experiences in the local environment can provide culturally accessible points of engagement from which to build science learning.

Descriptive measures provided an assessment of students' engagement in science activities, as well as their levels of thinking and learning throughout the school year. Combined with analyses of students' work files and focus group responses, these findings provided strong evidence of engagement attributable to the inquiry-based curriculum. In some instances, degree of engagement was found to be affected by student "reluctance" and "resistance," terms defined but needing further examination.

A confounding result showed marked increases in thinking levels coupled with stasis or decrease in learning. Congruent with past studies, data indicated the presence of tension between the diverse cultures of students and the mainstream cultures of school and science.

Findings were synthesized with existing literature to generate the study's principal product, a grounded theory model representing the complex, interacting factors involved in teaching and learning. The model shows that to support learning and to overcome cultural tensions, there must be alignment among three main forces or "causal factors": students, teaching, and school climate. Conclusions emphasize system-level changes to support science learning, including individualized support for students in the form of differentiated instruction; focus on excellence in teaching, particularly through career-spanning professional support for teachers; and attention to identifying key leverage points for implementing effective change.

*This dissertation is dedicated to all the young people
of the world ... may the adults figure it out in time.*

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As I near completion of this “terminal” degree, I am happy to take a few moments to reflect on the roles that so many people played...

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Dalton, where do I begin? I am honored to have had so much of your time and energy, particularly these past couple years. I have learned so much from you about culture, human interactions, and navigating complex situations. Your steadfast belief in my abilities truly impacted my motivation to continue, especially when the end seemed so far away. I promise continue your efforts, working for justice in education.

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It is safe to say I would not be finishing my dissertation if it were not for the support and understanding of my family and friends. Craig, they need to create an honorary PhD for supportive husbands, because you would certainly be awarded that honor. I do not see any way I would have finished had you not given me time away for writing, as well as the love and encouragement to continue. It is hard to believe we are nearing ten years—ten years of marriage, ten years of me being a student, ten years of you becoming the local expert on green, affordable housing development and rain-

water systems. I am very excited for the next ten years, and looking forward to more balance and time to continue building our lives together.

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At every milestone in my life, it seems I get all mushy about how I would not be the person I am today if it were not for my mom, but it is true. Mother, I wish you could have been here for my defense, but you can have your personal performance one of these days soon. Tina, having you here has been so wonderful, and even though our academic and professional pathways are slightly different, I am so glad there are areas of convergence. I still think the Merrels (now Schantz) sisters will make something happen. I am so excited to watch Wilder grow and to see you and Peter in your new role as parents. Taylor, I wish we saw more of you, but it is always nice talking about life, learning, and adventures with you. When Mother gets her presentation, maybe you will be there too.

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I am blessed with the most amazing friends in the world, and I have too many to acknowledge everyone. Nonetheless, some of you have had such impact on my life

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Connie, Bobbette, Tim, although we have not seen much of each other in recent years, your influence in my life runs deep. Those years on 9th Street were my formative years for sure, and our adventures together have shaped my current endeavors.

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PREFACE

In these opening remarks I share my environmental science perspective, provide an overview of my work, and describe my professional and personal interests, in order to lay a foundation for the story I am about to tell.

I. Environmental Perspective

Sustainability

As an environmental scientist, I believe that we as a human society must alter our current trajectory on this planet; otherwise we are likely to lose our place in geologic history. My intention is not to paint a picture of gloom and doom, but to inspire hope and optimism that we can overcome the monumental ecological problems of our time. Nonetheless, what we have learned from microbiology, climate-change science, evolutionary history, and theories of system limits and exponential growth makes clear that the planet and its species are at risk unless humans make dramatic changes in patterns of consumption and production of waste. To some extent, the Earth has already been adjusting to regain balance, displaying natural disasters of increasing intensity, pandemic viruses and resistant bacteria, failing food and agricultural systems, and dying oceans, among other symptoms. However, the planet is resilient. If society makes significant, meaningful changes—changes that will likely improve quality of life as well—odds of survival for the human and other species will improve.

Earth is a planet with finite resources, yet humans have acted as if this is not so. Society's economic models have been based on continuous growth and consumption, regardless of impacts on natural resources, quality of life, and

biodiversity. My hope is that a better model will emerge from the recent collapse of the global economic system—a new model that values the common good and shared resources. Humans have consumed and destroyed limited resources in the name of progress, subsidizing corporations for the sake of the economy, allowing them to externalize the true costs of production. Decimated rain forests and loss of cultures in the Amazon basin have not been incorporated into the price of a 99-cent fast-food value meal; and, unfortunately, the 99-cent burger has also made it more difficult for sustainable businesses to compete. If sustainable practices prevail, emphasizing care and respect for humans and the planet, the 99-cent burger will cease to exist. Yet such change is necessary, as societies must consider the short- and long-term consequences of collective choices and actions.

To survive, humans must learn to live sustainably on this planet, and so must alter patterns of consumption and unfettered growth. Collectively, societies do not grasp the concept of exponential growth. System limits can be modeled by comparing Earth to a Petri dish. In a Petri dish, as bacteria grow exponentially, they deplete the pool of nutrients in the agar. When the system's (the Petri dish's) limits have been reached, life ends, and mass die-off occurs. In the case of Earth, the system is not as simple and contained, but as seen over evolutionary time, mass extinctions do take place when the system is pushed too far out of balance. Life goes on but is altered dramatically, along with the surrounding environment.

The notion of Earth as a superorganism, a fundamental principle of the Gaia hypothesis (Lovelock, 1988), has always resonated with me. Like any organism or

system, the planet is constantly adjusting to reach balance—homeostasis. When limits are pushed and the system is out of balance, dramatic and rapid changes occur. Earth is a system in flux.

Justice

With this environmental perspective as backdrop, next I fundamentally believe that unless social justice is built into global society—by social justice I mean all humans having their basic needs met—we will not achieve the necessary ecological sustainability. Humans have pushed system limits to the edge of collapse and have created monumental ecological problems. To solve these problems, all citizens must be empowered with adequate knowledge and skills; to me, this is the core of a just society, and essential for achieving ecological sustainability. With knowledge, society may achieve scientific and ecological literacy; without it, the human population will not have the collective capacity to solve the problems it has created. Young people will inherit these global problems; it is the responsibility of adults and current leaders to pass along the knowledge and skills necessary for the next generation to solve them.

As my work is driven by a passion for social justice and a desire to alter society's ecological trajectory, I believe that for society to be successful at either, the educational systems need to be a central component of the solution. This is the specific reason why the focus of my dissertation is a science education research project.

The United States public education system is one of its largest institutions, and the main one dedicated to preparing young people for the world. It is responsible for helping students develop the knowledge, skills, understandings, and attitudes needed

to make informed, wise choices, and it is therefore a critical element in solving social and ecological problems.

Shifting Paradigms

Everywhere, existing paradigms are shifting. The U.S. has its first African American president, and not only that, he seems to be one of the few people who could have stepped into the presidency during such dire times. He has led this country during his first months with more intellectual focus, logical reasoning, calm and balanced action, and collaborative ethic than any leader in recent times. Obama is the face of a new paradigm, and I am thrilled to be nearing the end of my doctoral work at such a time of change. Granted, the current economy is daunting, but the worldwide crisis is also a large part of what is allowing the paradigm to shift so rapidly. Ironically, as times have become tougher, people are spending more time at home, making more meals, growing more food, and spending more time with family and friends—all things that improve quality of life and help slow damage to the planet.

Into changing times and shifting paradigms, I present my dissertation. The study that it reports sits at an edge itself—between research paradigms, which is by way of explaining why Environmental Science is a good fit for this work. In some regards, Environmental Science has developed at the edge of the mainstream science paradigm, challenging the way we analyze the natural world, paying more attention to the function and structure of systems than decontextualized components of the systems. My challenge to the environmental sciences is to go one step further, and consider the role a social system—the educational system—plays in the development

and progress of environmental and systems science. I have always been a big-picture, systems-level thinker. For this research, I delved into developing an empirical data set appropriate to a traditional PhD; however, in the end I returned to the big picture, connecting the study to an overarching concern—the system of education. I have connected my findings with others’ in the literature to converge on a theoretical model intended to guide curriculum development, professional development, and school change. The model can be used to help understand the complexity of the educational system, with the ultimate aim of better engaging and educating young people, making them more scientifically literate adults and helping change societal patterns of growth and consumption.

II. Doing My Part to “Be the Change”

My own trajectory over the past decade has led me to realize that I am a systems thinker, but that despite what I always thought, most people do not see the world similarly as a complex web of interconnections, relationships, and interactions. I have always been able to identify problems and devise solutions that consider longer-term outcomes and consequences; I believe even greater emphasis on long-term thinking is now necessary. Society is at a point in history when we need solutions and decisive action. In the words of Albert Einstein, “we will not solve the problems of today with the same thinking that created them” (Einstein, n.d.).

Collectively, humans should be able to make systemic changes to move toward educational justice and ecological sustainability. As mentioned, I am excited to be transitioning to the next phase of professional life at a time when there is so much

opportunity to have an impact. I have been deeply connected to local communities for the 17 years I have lived in Portland, and this lived experience has helped me understand the issues, interactions, challenges, and opportunities in the Portland area and the Northwest region. I intend to keep doing my part.

Portland as a community and Portland State University as an institution want to be models of sustainability for the nation and the world. The necessary components exist, but currently I do not see them being coordinated, integrated, and organized in the best ways to achieve that goal. Here, too, I want to contribute.

Portland State University proudly displays its motto, “Let knowledge serve the city.” I firmly believe in the values behind that motto and believe it is the duty of higher education to let knowledge serve cities, communities, and people. I would challenge the leaders of the university and the city to continue pushing to make their goals of leadership become reality.

CHAPTER 1 – INTRODUCTION

Chapter Overview

In this chapter I provide an overview of the dissertation, introduce the context of the study, and present the research problem. Then I describe the study design and the theoretical approaches that guided the investigation.

1.1 Introduction

In 2004, the U.S. Department of Education's Magnet Schools Assistance Program awarded the Rivergate School District* a three-year grant to transform several of its highest-needs schools into an integrated arts, science, and technology magnet program, articulated from kindergarten through 12th grade. Six schools were originally involved in the program—four elementary schools, one middle school and one high school—all serving the same geographic area of the city. Unfortunately, progress in the development and implementation of this project was greatly complicated due to significant changes at each of the schools involved. Two of the four elementary schools were closed because of declining enrollment. The George Washington Carver Magnet School, which is the school discussed in this study, was converted from a middle school to a K-8 model during the third and final year of the grant (2006-07). The high school involved in the magnet program broke into four smaller academies during the 2005-06 school year, and had several administrators over the three-year period (Field notes, 2006; Northwest Regional Educational Laboratory [NWREL], 2007). The changes at the middle school and high school were made in part to avoid

* Pseudonyms have been assigned to all schools, districts, teachers, and students mentioned in this study.

consequences of having failed for three successive years to meet “Adequate Yearly Progress” under the “No Child Left Behind Act” (Field notes, August, 2006; Rivergate School District, 2006).

George Washington Carver Magnet School (Carver) became the main hub of activity for the grant, since both were focused on technology integration, inquiry-based practices, systems thinking, and the arts. As part of the magnet program, Carver contracted with Portland State University’s Center for Science Education (CSE) to provide support integrating science, inquiry, and technology, and to help assess the impacts on teacher development and student learning. Faculty and graduate students from CSE worked collaboratively with teachers and school administrators to build relationships and to implement programmatic changes.

The mission of the Center for Science Education is to enhance science teaching and learning through innovative education, research, and community outreach programs. The Center promotes a constructivist model of science education that uses technology, including personal computers, displays, and instruments, as a powerful tool to enhance science inquiry. In this model, teachers build learning activities around students’ existing knowledge, skills, and interests, and utilize the local environment—classroom, schoolyard, neighborhood, city settings—as a context for integrating curriculum. Through its programs, CSE aims to help students and teachers raise their capacity to participate in the community as informed citizens.

As mentioned, Carver was converted from a middle school in the final year of the grant. At the end of the previous year (2005-06), the long-time sixth grade science

teacher retired. Since the school was converting to a K-8 model, there was a great deal of uncertainty about enrollment numbers at each grade level and about ways programmatic changes were to be implemented. To help ease the transition, the school administration used the partnership with CSE to support science teaching at the sixth grade level, rather than re-hiring a new, full-time science teacher. As a result, I had the opportunity to co-teach sixth grade science while simultaneously conducting research on learning and teaching in science.

During the year of active co-teaching and throughout the process of data analysis, the goal was to build a better understanding of ways to implement, as part of classroom and administrative practice, teaching and learning strategies informed by empirical research. Specifically I investigated the ways that an inquiry-based science curriculum, contextualized in the students' own local environment, impacted their engagement, thinking and learning in science. As part of this investigation, I was interested in addressing deeper questions, including:

- How can we engage ALL students in science?
- How do we access and utilize students' social and cultural "capital" to help them bridge the divide between the language of science and learning and that of their everyday experiences?
- How do we accomplish these goals in urban classrooms, where outside influences such as school climate and larger system-level challenges often hinder, rather than support, best practices?

This dissertation presents the outcomes of a study that took place as part of the school-university partnership during the 2006-07 school year. The study employed an ethnographic approach to build a substantive “grounded theory” (for sense of this term, see Corbin & Strauss, 2008; Creswell, 2008), investigating the ways that students become engaged in and learn science. Findings in this investigation were derived from student-level data, but also considered the larger context of the school and district, representative of broader systems that sometimes support and sometimes hinder progress towards building scientific literacy among adolescent learners.

1.2 Problem and Purpose

Despite the role that scientific understanding plays in the lives of all people, most United States citizens are not scientifically literate (American Association for the Advancement of Science [AAAS], 1989). In science achievement and literacy, the United States has been falling behind industrialized and developing nations over the past decade. Findings from the Trends in Mathematics and Science Study (TIMSS) showed mixed results for U.S. students compared with their international peers. At the fourth grade level, U.S. students appeared to be falling behind in science, while students at the eighth grade level had made modest gains (Lemke & Gonzales, 2006; U.S. Department of Education [USDOE], 2006).

A more compelling argument for a gap between U.S. students and those in other nations can be found in results from the Program for International Student Assessment (PISA). PISA focused on measuring the scientific literacy of 15-year-olds by investigating the ways in which they apply scientific knowledge and skills to

different situations and real-life problems (Lemke & Gonzales; USDOE). When compared with 28 other countries in the Organization for Economic Cooperation and Development (OECD), U.S. 15-year-olds scored below the average of all the OECD nations, and ranked 19th out of 29 overall (Lemke & Gonzales; USDOE). Since scientific literacy—the ability to apply scientific knowledge and skills to everyday situations—is a major goal of many science organizations (AAAS, 1989; National Research Council [NRC], 1996, 2000; National Science Teachers Association [NSTA], 2003), the PISA results should be troubling to U.S. scientific and educational communities.

The vision of AAAS's *Science for All Americans* project (1989) has not been achieved, and scientific literacy remains low in all groups. Although there has been a slight increase in science performance at the elementary level (fourth grade), according to the National Assessment of Educational Progress, since 1996, U.S. students have shown a decrease in science achievement by the time they leave high school (USDOE, 2006). Furthermore, at all grade levels tested (fourth, eighth, and twelfth), the percentage of students at or above “proficient” was low. In 2005, only 29% of fourth and eighth graders were at or above proficient, along with only 18% of twelfth graders, both declines from results in 1996 (USDOE,).

Among culturally diverse learners and females, scientific literacy was even less prevalent (AAAS, 1989; USDOE, 2006). In the *Condition of Education 2006*, males were found to outperform females at all three grade levels tested (USDOE). Furthermore, gaps in science achievement persisted between White students and

students of color (Grigg, Lauko & Brockway, 2006). At the fourth grade level, the achievement gaps between White and Black students and between White and Latino students narrowed in comparison to the 1995 results; however, by eighth grade the slight narrowing of the achievement gap was not statistically significant, and by twelfth grade, although not statistically significant, the gaps actually increased (Grigg et al.). Taken together, these findings demonstrate the need to improve science education for all students, particularly those from diverse backgrounds and those marginalized from mainstream teaching and learning in science.

Science reform documents call for authentic science teaching and learning opportunities for all students (AAAS, 1989; NRC, 1996, 2000; NSTA; 2003). Authentic learning experiences can provide meaningful opportunities for the engagement of diverse learners in science and may help overcome the tensions that exist between mainstream approaches to science and the diverse sociocultural backgrounds of students. Inquiry-based, project-based, and other approaches to science education offer opportunities for infusing culturally congruent approaches to teaching and learning, but such opportunities have not been fully pursued (Parsons, 2008). One purpose of this paper is to contribute to the body of knowledge in science teaching and learning that can be used to help overcome the perennial lack of scientific literacy, particularly among low-income and minority populations.

Education involves many highly complex, interconnected systems that need to be considered when making knowledge claims regarding learning and teaching. Because of the inherent complexity of educational systems, it is difficult and

problematic to identify and separate the complex, interwoven elements of teaching and learning. It can be argued that breaking down the processes of teaching and learning into discrete influencing factors is not only difficult, but also inappropriate. However, it is necessary to frame individual studies within boundaries that are manageable and relevant, while maintaining a larger view of the inherent complexities involved with education and educational research. As I will argue, it is important to situate individual studies within a larger systems framework and to describe specific elements, but not in isolation from the broader educational systems. This provides relevance by identifying not only areas of influence to which a particular investigation contributes, but potential interventions of predictable influence.

With this systems view in mind, investigating the problems of the achievement gap between minority and low-income students and their White, middle-class peers involves many factors. Students each bring a broad array of interests, skills, challenges and experiences with them to school. Numerous student-level factors need to be considered by a classroom teacher who is expected to teach all students well. This leads to another significant problem—how to incorporate research-based best practices into the classroom. Teachers are faced with reform efforts and outside pressures from state and federal education agencies, as well as expectations from the school's administration. Furthermore, teachers range in skill, education, and understanding of teaching practices and student culture. Add to all of this the social interactions that take place in a classroom, and the result is a complicated array of factors that may be hard to control and that may or may not be conducive to any student's learning.

With these considerations in mind, this study was designed to examine further the problems of:

- The achievement gap between minority and low-income students (non-mainstream students) and their White, middle class peers (mainstream students);
- The challenges of implementing research-based best practices into classroom practice.

1.3 Overview of Study and Dissertation

In the following chapters, I will outline what we know about culture and learning, particularly as these relate to science education, and will stress the importance of excellence in teaching. I will discuss ways in which our current educational system and structures do not support excellent instruction and research-based, culturally sensitive learning and teaching in most public schools. Next, I will present my study involving sixth graders attending the North Portland, K-8 Carver School. I will contextualize the study in place and time, describing school culture and climate and discussing the science curriculum as it was planned and enacted. I will outline methodology, research design, and theory-building approach, then present findings and results. Here I will provide empirical evidence of students' engagement, thinking, and learning in science, then explore through focus-group and other data the varied and complex phenomena that impact science teaching and learning. Finally, I will then connect these findings to the literature, resulting in a grounded theory model

intended to capture and clarify the complexities of learning and teaching, in this setting and applicable to others.

One of the primary purposes of this dissertation is to build a case for better connecting research to practice and policy. Currently, policy-makers set the context and rules under which districts, schools, teachers, and students operate, but in many cases, the context set by policy-makers is contradictory to empirical researchers' understandings of good learning and teaching. Taking a systems thinking perspective, if the structures and systems are not in place to support best practices, then encountering best practices in classrooms will be the exception, not the rule. When they are encountered (or more importantly, when students experience them) effective, "best" teaching practices will be the result of individuals' efforts, not the outcomes of the system overall. On the other hand, if systems and structures were aligned to support best practices, it is highly probable that this would have positive impacts on teaching and student learning, as well as school climate, family involvement, and community development.

In the final chapters, where I present outcomes of the study, I will reflect on my experiences as a teacher/researcher, describing what took place in three sixth-grade science classes and the work I did to implement a research-based science curriculum, while investigating impacts on students. I will discuss the challenges, barriers, and opportunities that I encountered over the course of this teaching experience. Finally I will discuss, by way of a recommendation, an example of a potentially potent "leverage point" for system change.

CHAPTER 2 – THEORETICAL FRAMEWORK & LITERATURE REVIEW

Chapter Overview

In this chapter I provide a review of the literature relating to culture, learning, and science education, summarizing themes and concepts that provide the foundation for the grounded theory presented in Chapter 5. I then provide an overview of the theoretical and methodological frameworks that guided the research.

2.1 Problem & Purpose

Despite the need to develop a scientifically literate society (AAAS, 1989; NRC, 1996; NSTA, 2003), and collective efforts, over many decades, toward the goal of Science for All, we have yet to achieve these goals. Understanding of science and science inquiry is low among America's young people, especially among low-income and minority students and girls (Grigg et al., 2006; Lemke & Gonzales, 2006; USDOE, 2006). Our nation is not keeping pace with other nations in the fields of science, technology, engineering and math (Grigg et al.; Lemke & Gonzales). As people across the planet struggle to build local economies that support global sustainability, increasing scientific literacy—people's ability to utilize scientific understanding in everyday, real-world situations—is more important than ever.

Excellence in teaching is a critical factor in ensuring that young people gain the knowledge and skills necessary to be scientifically literate, and if closing achievement gaps is a serious goal, excellence in teaching should be particularly critical in high-poverty and high-minority schools. Nonetheless, such high-needs schools employ a disproportionate number of inexperienced and underqualified teachers compared with schools serving other students (Peske & Haycock, 2006).

Despite evidence that new teachers require several years of classroom experience to reach their full potential (Laurence, 2007; Peske & Haycock), high-poverty and high-minority schools are twice as likely to have new teachers as are more affluent schools (Peske & Haycock). Additionally, at the high school and middle school levels, high-poverty and high-minority schools are more likely to have teachers teaching outside of their content areas (Peske & Haycock). Significant evidence has correlated teacher experience and student performance, indicating that student performance improves substantially after teachers have gained two to four years of classroom experience (Laurence; Peske & Haycock).

Ingersoll (2001) described the extent to which U.S. schools still face problems of low teacher retention, despite the documented importance of teachers' on-the-job experience from their first few years of teaching. Schools lose significant numbers of teachers, particularly in science, math, and special education, through "a 'revolving door,' where large numbers of teachers depart their jobs for reasons other than retirement" (p. 5). According to Ingersoll, teacher recruitment initiatives alone do not address shortages of high-quality teachers without attention to "organizational sources of low retention" (p. 5).

These data point not only to the importance of slowing the revolving door of teacher attrition, but to the need to ensure high-quality teaching in the highest-needs schools. Achievement gaps (discussed in more detail in Section 2.2.5) and other educational impacts of inequitably distributed resources have been the topic of many studies and position papers; economic impacts of achievement gaps and teacher

turnover have also been found to be significant. McKinsey and Company, Social Sector Office (2009), outlined empirical evidence for economic impacts of achievement gaps, in order to provide a basis for understanding the human impacts of these gaps. Individuals with lower academic achievement have lower earning potential, poorer health, and higher rates of incarceration (McKinsey & Company). Furthermore, figures showed, the U.S. loses significant Gross Domestic Product (GDP—ironically, a pervasive icon of a consumption-based economic model), due to national and international achievement gaps, in amounts comparable to a “permanent national recession” (p. 6). The United States loses billions of dollars in potential GDP annually due to domestic achievement gaps, and trillions due to gaps between the U.S. and other nations (McKinsey & Company).

To accomplish goals of scientific literacy, ecological sustainability, educational justice, and economic potential, it is necessary to improve and update educational systems to support students and teachers. Despite an extensive base of knowledge about teaching and learning from which to draw, many areas of study in educational improvement have remained largely disconnected. There is a need to synthesize and build upon collective understandings of the ways people learn, mobilizing the resources these understandings represent to build a strong educational system that serves all young people.

2.2 Culture and Learning in Science

2.2.1 Principles of Learning

Through cumulative understanding from cognitive science and educational psychology, and from research on teaching and learning, it has become clear that learning with understanding is an evolving, complex process that takes place within each learner as she navigates a social world. The learning process is influenced by many factors including the context of learning activities, students' past experiences and cultural backgrounds, teacher practices, school climate, and parent and community support (Atwater, 1994, 1996; Bransford, Brown, & Cocking, 2000; Brown, Collins, & Duguid, 1989; Lambert & McCombs, 1998; Marzano, 1992). The American Psychological Association (Lambert & McCombs), the National Research Council (Bransford et al.), Regional Educational Laboratories (Marzano), and other education organizations have synthesized educational research to identify principles of learning. These principles use different organizational frameworks and language; however, in general, they present the same basic ideas.

One example is the American Psychological Association's Learner-Centered Principles, articulated by Lambert and McCombs (1998) and others. The 14 Learner-Centered Principles primarily relate to learners themselves, but also take into account external factors. These psychological principles are divided into four categories: Cognitive and Metacognitive Factors, Motivational and Affective Factors, Developmental and Social Factors, and Individual Differences. Together, these principles acknowledge that learning is an active process, influenced by prior

knowledge and experiences, attitudes and motivation, and individual patterns of development (Lambert & McCombs).

Marzano (1992) and others from the Mid-Continent Regional Educational Laboratory identified five Dimensions of Learning from their synthesis of the literature. Dimension One refers to the attitudes and perceptions that students have regarding their learning, abilities, and interests. Dimension Two concerns the processes learners use to acquire and integrate new knowledge, relating it with existing conceptual understandings and organizing information into their memory schemata. Dimension Three comprises ways that learners extend and refine their knowledge and understanding, using processes such as comparison, classification, inductive and/or deductive reasoning, and analysis. Dimension Four refers to the ways students use knowledge to perform meaningful tasks such as decision making, problem solving, and experimentation. Finally, Dimension Five refers to productive habits of mind including critical thinking, creative thinking, and self-regulated learning (Marzano).

A third and well-known synthesis of educational research comes from the National Research Council. Similar to the Learner-Centered Principles and Dimensions of Learning, Bransford, Brown, and Cocking (2000) and others derived several overarching principles of learning. First, learners bring an array of preconceptions, which must be tapped into for new learning to occur. Furthermore, learning is an active process, and to develop competencies, learners need to have a deep understanding of factual knowledge, and to understand facts and ideas within a

larger conceptual framework. New learning must be organized into existing knowledge structures so that it is accessible and lasting. Finally, the role of metacognition is important so that learners can take control of their learning process, set goals, and develop strategies for monitoring those goals (Bransford et al.).

Although each of these syntheses articulates the findings slightly differently, there are commonalities among them. Each set of principles recognizes the importance of identifying and accessing learners' prior knowledge and experiences, and all address the active nature of learning and discuss ways that new knowledge must be incorporated into existing knowledge frameworks for learning with understanding to take place. Finally, all address the important role that reflection and metacognition play in the learning process (Bransford et al., 2000; Lambert & McCombs, 1998; Marzano, 1992).

Applying these principles of learning in a classroom setting seems straightforward in theory. A learner-centered classroom would provide many opportunities for students to actively process experiences with the insightful facilitation of a skilled teacher, helping them integrate new information with existing knowledge schemata (Caine & Caine, 1997). A productive classroom feature described by Caine and Caine is that of "relaxed alertness"—moderately high level of challenge with low level of threat. In such an environment, learners would have the space and comfort to make learning meaningful, to make connections, and to integrate learning (Caine & Caine, 1991). With teachers' support, students would be able to activate their prior knowledge and construct new understandings.

The different ways of organizing and utilizing research-based principles of learning provide similar interpretations of empirical findings in science education and education in general. The importance that excellence in teaching plays in learning has been well supported. This dissertation endeavors to synthesize the principles presented above with research on culture and education, specifically in science, in building its grounded theory. The theory is intended to inform research, practice, and policy supporting excellence in teaching, for the benefit of learners and learning.

2.2.2 Science Education Research

Turning to science education, it should not be hard to imagine good science teaching incorporating these student-centered principles of learning. In fact, calls for more opportunities for inquiry-based science learning are well-aligned with what we know about the ways people learn, and inquiry-based teaching and learning practices are congruent with the developmental needs of young adolescents—the age group of the students in this study. Young adolescent learners need activities that allow them to interact directly and actively with the world around them. Such activities help them transition their conceptions from concrete experiences to abstract understandings (Caskey & Anfara, 2007).

Inquiry-based, project-based, experiential, and place-based learning in science can provide opportunities to implement basic principles of learning. There are several excellent examples in the literature of inquiry-based and project-based science, aligned with national science standards, having positive impacts on students, including reducing the achievement gap between White students and their low-income and

minority peers. Furthermore, in these examples, technology-enhanced inquiry had even more pronounced results.

In their seminal work, White and Frederiksen (1998) investigated impacts of using a technology-enhanced, inquiry-based physics program with students; for some test groups they also incorporated a metacognitive strategy component. The researchers found pronounced improvements among students who experienced the inquiry-based teaching approach and even greater effects for the students who also used the metacognitive strategies. White and Frederiksen found even greater increases in achievement levels among traditionally lower-performing students. The authors believed this finding was a result of the higher-achieving students already having better developed metacognitive skills, whereas the lower-achieving students did not (White & Frederiksen). Their study strongly implicates the necessity of building metacognitive skills, particularly for lower-performing students. This experimental study took place in 12 classrooms in two schools; implementation of its recommended strategies is still far off, considering the number of public schools across the nation.

Perhaps showing greater promise for implementation through larger-scale interventions is a program study by Marx and his colleagues at the Center for Learning Technologies in Urban Schools (LeTUS). Through LeTUS, a partnership between Detroit Public Schools and the University of Michigan, 8000 students participated in a technology-enhanced science curriculum. Researchers found statistically significant increases in achievement, with increasing effect size for each year students

participated. Furthermore, they also showed positive results for traditionally under-achieving students (Marx et al., 2004).

According to Marx and colleagues, many of the key features of the LeTUS curriculum aligned with the principles of learning discussed earlier. The partnership involved an intensive process of designing, developing, and enacting the curriculum. Its critical features included setting of learning goals based on national standards, use of driving questions to contextualize curriculum, and structuring of activities and lessons to prepare students for investigations. Furthermore, technology provided scaffolding for student learning, and included features such as modeling and information searching. Student artifacts were used to determine understanding, and provided topics for discussion and formative assessment (Marx et al., 2004).

Teacher professional development was an integral component of the partnership, with an understanding that enactment of the intended curriculum was as important, if not more so, than the curriculum itself (Marx et al., 2004). The researchers acknowledged:

Teachers cannot simply move to inquiry approaches to instruction from recitation and direct instruction. They need to learn many new ideas about students, learning, curriculum, pedagogy, and assessment. (p. 1066)

Through a professional development framework called CERA—Collaboration, Enactment, Reflection, Adaptation—teachers participated in summer institutes, monthly work sessions, and discussion groups. The overarching goal of professional development activities was to prepare teachers to enact curriculum in alignment with the theoretical basis, while adapting to specific classroom circumstances (Marx et al., 2004).

LeTUS and other studies looked specifically at student outcomes; however, as with the LeTUS emphasis on professional development, they also contributed to the notion that society must adequately prepare and support teachers to be successful in the highly complex work of educating young people. Laurence (2007, p. 94) proposed a “reVisioning” model that elucidated the need to provide teachers with access to timely and appropriate supports. She described the ways in which a teacher’s personal and professional needs change and evolve over a career, requiring that support systems be adaptive enough to respond teachers’ changing needs for professional growth (Laurence, 2007).

Regarding system-level issues, while LeTUS was an example of large-scale success in an urban district, the authors also reported that systemic conditions were not always ideal. Teachers’ time and priorities were pulled in other directions, pressures existed from high-stakes testing, and challenges arose with technology infrastructure, to name a few hindrances (Marx et al., 2004). Furthermore, as seems to be the case in education, the initiative seems to have perished along with the initial funding stream. This raises the question of how educators can cause lasting, systemic changes if the underlying structures and functions do not shift as a result of successful partnerships and programs.

The studies presented thus far have not included explicit reference to culture. Although the topic of culture and learning has emerged in science education and other disciplines, it is often a topic separate from a large portion of the programmatic and research work. In the next section, I will present a brief overview of culture and its

role in learning, and argue that the concept of culture should be considered central to our cumulative understanding of teaching and learning.

2.2.3 Defining Culture

A discussion about learning and teaching in science would not be complete without a deeper discussion of culture. Culture is much more than simply the ethnic classification of individuals; rather, it represents complex systems by which groups of individuals interact and share meaning. In defining culture, two interrelated concepts have particular relevance for this study—cultural practices and cultural meaning systems.

First, culture consists of the activities or cultural practices in which individuals participate and engage (Cole, 1996; Gutierrez & Rogoff, 2003). These activities also include cultural tools such as language and communication patterns (Cole). This explanation of culture is important in education because to gain an understanding of what is important to students, it will be necessary to know how they spend their time outside of school, and the types of activities they are motivated to learn and do well. Most students are motivated to learn and to be competent; however, sometimes teachers and others do not recognize what students are trying to master. By looking at the activities they participate in and practice, one gains insights into their motives and values, as well as the organization of their repertoires of cognitive strategies.

Another defining aspect of culture concerns the ways individuals attribute meaning to events or experiences. As D'Andrade (1996) said:

It is assumed here that culture consists of learned and shared systems of meanings and understanding, communicated primarily by means of natural

language. These meanings and understandings are not just representations about what is in the world; they are also directive, evocative, and reality constructing in character. Through these systems of meanings, individuals adapt to their physical environment, structure interpersonal relationships, and adjust psychologically to problems and conflicts. (p.65)

Culture, then, can be described as the language, norms, and interaction patterns of groups of individuals, as well as the ways in which they make sense of the world. This broad definition of culture provides the foundation for my work, study, analyses, and interpretations.

In their seminal piece, “Cultural Ways of Learning: Individual Traits or Repertoires of Practice,” Gutierrez and Rogoff (2003) described a cultural-historical approach to education and educational research, showing it to be a means of overcoming generalizations about individuals belonging to particular social groupings. They argued that often, professional development to help teachers understand diversity will focus on individual traits rather than past experiences and participation in the activities of a community—or, for example, on individual learning styles. They stated:

A cultural-historical approach can help researchers and practitioners characterize the commonalities of experience of people who share cultural background, without ‘locating’ the commonalities within individuals [I]n this approach ... the structure and development of human psychological processes emerge through participation in culturally mediated, historically developing, practical activity involving cultural practices and tools. (p. 21)

Using a cultural-historical perspective, the researcher can expect a better understanding of regularities and patterns that develop within particular cultural groups; however, such an approach also helps reveal variations in the ways individuals respond to activities and experiences (Gutierrez & Rogoff, 2003). Cultural-historical

and sociocultural perspectives help situate teaching and learning in the context of norms, values, and practices of cultural communities.

Situated teaching and learning place culture at their center. In the situated perspective, learning activities of any domain are socially constructed within a cultural context, and the process of learning is a process of enculturation (Brown, Collins, & Duguid, 1989). As Brown and colleagues (1998), pointed out, activities in school are implicitly framed by one culture—the mainstream, dominant culture—but explicitly applied to all the other cultures represented in school. Furthermore, school practices, in general, assume that knowledge is individual and self-structured, rather than socially constructed through meaningful learning activities. Although school activities often encourage problem solving, they disregard the diverse array of strategies that students may bring from their home cultures and everyday experiences (Brown et al.).

Lemke (2001) specifically articulated the cultural-historical/sociocultural perspective as it relates to science education. First and foremost, he pointed out that “... science, science education, and research on science education [are] human social activities conducted within institutional and cultural frameworks” (Lemke, p. 296). He pointed out that the cultural underpinnings of “normative” science and science education are often in conflict with the cultural norms and practices of non-mainstream students. Furthermore, similar to Gutierrez and Rogoff’s concern that it is easy to oversimplify differences in individual traits, Lemke pointed to the tendency of educators and researchers to foreground particular sociocultural characteristics when thinking about particular racial or demographic groupings, meanwhile ignoring other

factors. For example, he mentioned that with African American students, educators tend to focus on race, but pay less attention to language or social class. For Latino students, the focus may be on language over race and social class (Lemke).

With sociocultural and cultural-historical approaches, emphasis is on the organization and context of classroom communities. Lemke (2001) articulated, in my estimation, the central problem that this dissertation attempts to address. He stated:

We inherit a social ideology, especially in the United States, which says that by heroic efforts of underpaid teachers, it is possible to create classrooms of 30 to 40 students with an arbitrarily high degree of social, cultural, and linguistic diversity who will nevertheless learn science at exactly the same rate and with equally high and broadly distributed levels of achievement compared with, say, classrooms of 20 to 30 students who share substantially similar background and learning needs. On the other hand, we also inherit an organized school system which pays no attention to teaching students the lessons of working across age diversity ... or learning to connect ... school learning to learning and action outside school. We inherit a system of schooling that rips apart arduously constructed classroom communities and teacher-student social relationships every 4-9 months—almost as soon as they are well enough established to produce mutually supportive insights. The organized efforts of many people in our field today are focused on setting curriculum achievement standards and promulgating more intellectually authentic teaching methods, but more basic institutional, social, cultural, and linguistic prerequisites for school success are still not being taken seriously. (p. 306)

In this long segment from “Articulating Communities,” Lemke implicated the systemic challenges faced by scientists, science educators, and education reformers. As he pointed out, if these professional communities do not look seriously at system-level influences related to culture, teaching, and learning, as well as the structures and functions of the system overall, they will not reach full potential in educating young people.

2.2.4 Classrooms as “Cultural Interface Zones”

Working with language and culture is inseparable from the practice of science education; Science for All does not equal one size fits all. Cultural differences result in diverse learning styles, ways of knowing, and educational needs (Lynch, 2001). Nonetheless, many mainstream science teaching practices are not supportive of learning styles common among African American students and other diverse learners. In their extensive reviews of the literature, both Atwater (1994) and Lee (2005) found that many ethnic groups are visual, holistic learners and tend to utilize metaphors more than mainstream students do. Students bring to the classroom a diverse array of language and communication styles, cultural experiences, and previous learning and understanding. Teaching needs to capitalize on these student assets, while Anglo-European language patterns should not be perceived as the best or only way to communicate (Atwater; Lee, O.). Unfortunately, Western science often invalidates or marginalizes the cultures and practices of diverse groups. The norms, values, and knowledge claims of Western science tend to be viewed as superior and more valid than other ways of knowing—for example, indigenous ways of knowing. This view, particularly through its influence on diverse learners in the classroom, has contributed to the gap in scientific literacy (Lynch).

Although students are often not equipped with the language and tools of mainstream science, they bring their own understandings of the way the world works, and these understandings are based in their everyday, lived experiences. Warren, Ballenger, Ogonowski, Rosebery, and Hundicourt-Barnes (2001) described the

heterogeneous nature of scientific sense-making, and the need to better connect students' everyday language and problem solving abilities with those required in school science. They referred to everyday knowledge as improvisational, ambiguous, informal, engaged, and subjective; compared to scientific knowledge that is rational, precise, formal, detached, and objective (Warren et al., 2001).

In her review of research on cultural diversity in classrooms, Atwater (1994) described characteristics of "field dependent" learners. Field dependent learners are highly influenced by the context (the "field") in which knowledge and skills are embedded; they tend to do better in social settings, and they are influenced by others' opinions. Field dependent learners also tend to use more deductive reasoning and are more global in their thinking. They can be less likely than field independent learners to choose science and math courses and careers. Atwater also found that more African American (males and females), Mexican-American (males and females), and White women were field dependent than White males (Atwater).

Another example of difference between the culture dominant in mainstream schooling and students' own cultural orientations is found in work related to Afro-cultural ethos (Boykin & Ellison, 1995), or Black Cultural Ethos (Parsons, 2008). Boykin and Ellison described nine aspects of Afro-cultural ethos, including spirituality, harmony, movement, verve, affect, expressiveness, communalism, orality, and social perspectives of time (Boykin & Ellison). Parsons focused on three of these characteristics—verve, movement expressiveness, and social perspectives of time—in her study investigating ways that infusion of Black Cultural Ethos (BCE) improved

the performance of African American students. Her study shed light on the tensions that often occur in urban classrooms when African American students are expected to conform to the participation structure and culture of mainstream education, which is divergent from Black Cultural ethos (Parsons).

Taken together, the findings from research described to this point provide evidence of tension and conflict between the culture of mainstream science and science education, and the cultures that students bring from their homes and communities (Norman, Ault, Bentz, & Meskiman, 2001). Norman and colleagues described classrooms as cultural interface zones—places where divergent cultures meet, interact, and respond to activities and situations. However, based on simple demographics, a diverse student population is taught by a generally homogeneous teacher population (Norman et al.). Power imbalances are common in these cultural interface zones, in that teachers consciously and/or unconsciously reflect society's notion of who or what is privileged. Norman and colleagues went on to say that students and teachers usually are not prepared to navigate the complexities of cultural interface zones. Teachers need training and support in order to develop learning environments that are based on cultural cooperation; otherwise, classrooms are likely to become sites of cultural conflict, hindering student learning (Norman et al.).

Fortunately, multicultural education, when done well, has been shown to help bridge these cultural gaps and to improve student learning (Atwater, 1994; Lee C.D., 1998; Norman et al., 2001; Parsons, 2008; Warren et al., 2001). Teaching in multicultural classrooms transforms classrooms from zones of cultural conflict to

zones of cultural cooperation. To do this, teachers must access and incorporate the skills, knowledge, and experiences that students bring to the classroom; even behaviors that seem like “oppositional responses” to classroom activities should be viewed as “cultural capital” that can enhance learning (Norman et al., 2001).

Atwater (1996) identified five primary foci of research in effective multicultural science education, including science learners, science teachers, science curriculum, classroom context, and assessment and evaluation. Research she cited pointed to the significance of variations in learning and communication styles, and supported the notion that students’ verbal and non-verbal communication patterns are learned through participation in their own diverse communities’ cultural activities, explaining why these distinct patterns must not be ignored (Atwater).

Teacher-student and student-student interactions are critical components of the classroom environment, and can impact learning either positively or negatively. When different cultural groups interact in the classroom, these interactions can result in conflict if students and teachers are not provided with specific, meaningful, understanding-building opportunities to interact and work together (Atwater, 1996).

Rodriguez has taken the notion of multicultural education—a theory of social justice—and combined it with constructivism—a theory of learning—to describe Sociotransformative Constructivism (STC) (Rodriguez, 1998). He asserted that this framework offers an improved means of explaining the ways that social, historical, and institutional contexts affect learning and access to learning. Sociotransformative

constructivism is a tool for examining the ways power, privilege, ethnicity, gender, and voice influence what is to be learned, as well as when and how (Rodriguez).

In line with principles of learning described earlier, Rodriguez elaborated four elements of STC. First, dialogic conversation—a “trust-centered” construct—should be employed to provide a means for individuals to listen to and understand one another. Second, learners must have opportunities to engage in authentic activities, in which the diverse backgrounds that they bring to learning are used as tools to enhance learning. Third, metacognition and reflection are essential for students to develop awareness and control of their own learning. Finally, STC depends on reflexivity, which is an awareness of the ways that social contexts influence what we think is important to learn, inviting an exploration and transformation of the culture of power (Rodriguez, 1998).

To summarize, since diverse learners bring with them diverse arrays of knowledge and experiences, it is essential to utilize culturally responsive educational practices. Research shows that traditionally underachieving students can perform at high levels when education is culturally responsive (Lee, C. D., 1998). When teachers adapt subject-matter content to reflect the culture(s) of students, they help students learn more about their own culture and the cultures of others. Culturally relevant education recognizes and validates varied student experiences and uses those experiences as “scaffolding” to structure educational activities. It contextualizes content and expands the curriculum. In doing so, it empowers students intellectually,

socially, emotionally and politically (Qualls, 1998). Culturally relevant education builds on the language and culture of students (Tate, 1995).

2.2.5 Gaps in Achievement and Opportunity

Alas, many of the ongoing discussions about achievement gaps do not directly include concepts of culture and language, or important related concepts. And although there has been a considerable amount of discussion and concern over the achievement gap between ethnic and cultural minorities and low-income students on the one hand, and their White, middle-class peers on the other, very little progress has been made in eliminating this gap (Jencks & Phillips, 1998; Madhere, 1998; Norman et al., 2001). Furthermore, despite clear evidence that quality teaching is one factor, if not the most important factor, in helping students learn and in closing achievement gaps, there is a persistent societal myth that what teachers do in the classroom cannot compensate for students' lives and backgrounds (Dobbie & Fryer, 2009; Pensk & Haycock, 2006).

Disparities in opportunity are at the core of the achievement gap (Norman et al., 2001). The principal disparity involves poorer access to high-quality, culturally-relevant education for students of diverse backgrounds. Disparity can emerge when teaching practices are not supportive of the learning styles of African American, Latino, Native American, and female students (Atwater, 1994, 1996; Lee, O., 2005; Warren et al., 2001). Often, teaching practices used with marginalized student populations stress memorizing and recalling isolated facts, rather than the development of higher-level thinking skills used with more privileged students (Norman et al., 2001). Diverse students are more likely to be relegated to passive

learning situations, with subject matter taken out of context, and they are less likely to have opportunities to use alternative approaches to problem solving (Madhere, 1998). Teachers may even discourage dialogue between students and teacher as well as among students, limiting the sharing of approaches (Madhere). Perhaps some of these findings are due to high-poverty and high-minority schools having fewer experienced and highly-qualified teachers (Penske & Haycock, 2006).

Synthesizing findings from several lines of educational research—principles of learning, cultural and critical studies, science education, and teaching practices—the quality of a student’s educational experience, her time in school, emerges as being of the utmost importance. However, studies from the same literature also demonstrate the importance of overarching structures in educational systems. For example, policy analyses indicate that inequities in distribution of high-quality teaching probably result, at least in part, from district-level hiring policies and budgeting procedures (Penske & Haycock, 2006). Marx and colleagues (2004) and others have discussed the systemic challenges to capacity-building and teacher support. There is evidence that test scores decrease more over the summer months for economically disadvantaged students (Jencks & Phillips, 1998), reinforcing the importance of school time, but also demonstrating the role that out-of-school time plays in students’ lives and learning. This highlights the need to consider, and even builds support for, the notion of changing the structure of the school day and school year. There is preponderant evidence that the achievement gap reflects the sociocultural position of groups, ranging from dominant to marginalized, a fact demanding change beyond what

teachers and students alone can accomplish in the classroom. These works strongly suggest that improvements to the educational system would better support research-based best practices in teaching and learning.

Inattention to culture and language; disparity in opportunities, access, and resources; and structural problems all play a role in achievement gaps. Sociocultural factors, however, may not only be at its root but a key to its elimination (Norman et al., 2001). Norman and colleagues (2001) proposed a “functional approach” to incorporating culture into teaching and learning—an assets-based approach, in which students’ differences provide a basis for building cooperation and understanding, enhancing rather than impeding learning. In theory, this approach seems ideal and almost obvious; however, putting it into practice is a challenging undertaking for teachers, and points to the critical role of classroom teaching practice.

Until there are concrete changes in classroom practices that address issues of race, language, culture, gender, position and power, one cannot expect much change in the academic success of diverse learners (Jencks & Phillips, 1998). And unless policies at the school, district, state, and federal levels support changes in classroom practice, specifically research-based changes shown to build excellence in teaching diverse learners, the achievement gap will persist.

2.2.6 Ensuring Excellence in Teaching

Excellence in teaching seems to be the single most important factor in closing the achievement gap (Dobbie & Fryer, 2009; Jencks & Phillips, 1998; Penske & Haycock, 2006), ensuring that all students receive the best possible education— and

building a scientifically literate population. For, as discussed, in today's society it is critically important for all citizens to have a basic understanding of science and the ways it affects daily lives and decision-making (AAAS, 1989; NRC, 1996, 2000; NSTA, 2003).

Embedded in science education reform is the belief that rigorous standards, quality curriculum, and effective teaching (including some form of inquiry) equal robust learning and achievement for all students (Warren et al., 2001). Beyond these, research has found that multicultural education is needed to help bridge gaps between the culture of mainstream science and the cultures of students.

Despite the clear need, there is still too little on-the-ground support for teachers and schools trying to develop teaching excellence and implement multicultural educational practices. There is a need to support teachers throughout their teaching careers, providing access to timely and appropriate opportunities for professional growth and renewal (Laurence, 2007). Furthermore, the demands on teachers working in high-needs schools are even greater, requiring a deeper understanding of culture and a wider array of teaching strategies. Recommendations from Levine (1994) and Marx and colleagues (2004) support organizing networks of support for teachers that span their entire teaching careers. In her extensive analysis of secondary data, Laurence (2007) identified the importance of mentoring and induction programs for new teachers, and also emphasized the need to support teachers during the second stage—years four through ten—when teachers often make their decision to commit to a career in teaching or to leave the profession. Laurence emphasized the importance of

connecting teachers to accessible, appropriate, and timely supports that meet their needs for professional growth and renewal (2007).

Despite our collective understandings of learning and teaching, multicultural education, and inquiry-based science, there is a lack of empirical evidence on ways to change classroom practices (Rodriguez, 1998). Teaching inquiry is in itself often a large shift in pedagogical practices for teachers, requiring extensive support and professional development (Marx et al., 2004). When teachers simultaneously work to identify and incorporate students' sociocultural backgrounds in meaningful ways, the challenge increases. Most teachers come from the same sociocultural backgrounds as the mainstream culture of school and science (Boykin & Ellison, 1995; Norman et al., 2001). This reality makes it even more important to help teachers gain cultural awareness and understanding, and to develop multicultural educational strategies.

Studies involving pre-service teachers have found resistance to making ideological and pedagogical changes related to inquiry-based science and multicultural education practices (Rodriguez, 1998); these studies align with preliminary findings presented by Laurence, Kelley, Becker, Day and Marshall (2006). Although not including it in their final framework, Laurence and colleagues (2006) identified the influence of personal values and beliefs as a "critical juncture" in teacher education. Critical junctures were challenges that teachers encountered as they learned and developed new practices "that may cause teachers to doubt their ability and skills, or call into question the validity of new practices" (Laurence et al., p. 2). In the case of personal values and beliefs, the authors pointed to tensions between teacher beliefs

regarding curricular goals and expectations about them from administration (Laurence et al.). Teachers in Laurence's and colleagues' study provided insights regarding the ways teachers navigated critical junctures to move forward in their own learning, providing improved instruction for students (Laurence, Kelley, Becker & Day, 2007). Consistently, teachers identified time as an overarching limitation—time to collaborate, time to plan, and time to reflect. Additionally, interventions that were most effective in helping teachers navigate critical junctures were appropriate supports (i.e., teacher-driven focus for daily professional development activities); access to experts, information, and colleagues; and readily available support with technology (Laurence et al., 2007).

There is a vast assortment of materials, research summaries, curriculum, and “how-to” books available to teachers. What seems to be lacking most is time to learn and grow professionally (Laurence, 2007), as well as institutional and systemic support for ongoing improvements and changes to classroom practices (Levine, 1994; Marx et al., 2004; Penske & Haycock, 2006). Levine (1994) emphasized this point in his document summarizing effective instructional practices and interventions for African American students. He discussed specific practices such as use of graphic organizers, technology-enhanced instruction, formative assessment, and cooperative learning, while also acknowledging that to transform the classroom, teachers need ongoing professional development and technical assistance, as well as a positive school climate, supportive leadership, and high student expectations (Levine). Furthermore, in order to make changes and improvements, Levine (1994) emphasized

that larger, systems-level issues need to be addressed. He stressed that changes will not extend beyond a few scattered classrooms unless innovations are implemented and supported at a systemic level (Levine).

Through the LeTUS partnership with Detroit Public Schools, mentioned previously, Marx and associates (2004) discussed system-level challenges that affected implementation of their technology-enhanced, inquiry-based science projects. Consistently through the program, they found that teachers and schools faced competing priorities, including instructional demands from high-stakes testing. Similarly, they reported that teachers' time and efforts were devoted to other science initiatives and professional development opportunities, pointing to a need for consistency, intentionality, and clear priorities. They also reported high levels of teacher mobility, as well as frequent change in leadership at the school and district level (Marx et al., 2004).

Fortunately, Marx and associates (2004), made recommendations regarding the implementation of district-wide, technology-enhanced science reform, based on lessons learned from the LeTUS partnership. One of the key factors they identified in the partnership's success was that the work was embedded in the context of systemic reform, with district leaders working directly with researchers to realign district policies to enable standards-based instruction. Furthermore, they stressed that collaboratively developing the curriculum with teachers was fundamental, empowering them to "be tenacious and to persist toward shared goals" (p. 1076). Professional development activities provided teachers opportunities to learn

collaboratively, helping them develop the knowledge and skills necessary to support students engaged in technology-enhanced inquiry projects. Finally, assessments aligned with the standards-based curriculum (Marx et al., 2004).

2.2.7 Toward a Systemic Model

Despite vast amounts of research looking at science teaching and learning, including contexts of learning, student attitudes and engagement, cultural factors, and classroom interactions, few studies tie it all together for practical application. The excellent work of Rodriguez, Marx, and others still falls short of creating a whole picture, inadequately examining links among community, classroom, school, system, and professions, and pragmatic ways to improve the whole. The study presented in this dissertation looked deeply at the ways students' engagement, thinking, and learning in science were influenced by classroom climate and school culture. From this study and themes identified in the literature, I have developed a grounded theory model to help understand the highly complex phenomena involved with learning and teaching, and to view that complexity from a systems-level perspective. The grounded theory, to be presented in Chapter 5, is pragmatic in nature and should be useful for practice and research, as well as informative for policy.

2.3 Methodology

2.3.1 Pragmatic, Sociocultural Perspective

To build a better understanding of the complex phenomena that take place in a science classroom, I needed a methodological approach that would allow me to look at a large number of divergent data sources and that would employ tools ensuring clarity

and insight. Philosophically, I drew from sociocultural and critical education perspectives, which provided a broad, theoretical lens to view data and to make claims. Pragmatism provided the methodological framework for analyses and interpretations, and systems thinking provided a set of tools for describing and explaining the phenomena.

Critical theory is a conceptual lens—and a powerful theoretical framework—that views schools as institutions that maintain social and cultural power systems through underlying structures embedded in curriculum. In this view, schools tend to perpetuate oppressive practices of society, and provide little opportunity for student empowerment (Atwater, 1996). In critical theory, a goal of educational research should be to identify and challenge these underlying oppressive practices.

Employing a pragmatic approach, I utilized mixed methods to investigate the complex phenomena of teaching and learning in an urban, middle school science classroom. As described by Johnson and Onwuegbuzie (2004), pragmatism “rejects traditional dualisms ... [and] prefers more moderate and common sense [sic] ...” approaches to problem solving (p. 18). The authors describe how everyday ...

... [h]uman inquiry (i.e. what we do in our day-to-day lives as we interact with our environments) is viewed as being analogous to experimental and scientific inquiry. We all try out things to see what works, what solves problems, and what helps us to survive. We obtain warranted evidence that provides us with answers that are ultimately tentative (i.e., inquiry provides the best answers we can currently muster), but, in the long run, use of this “scientific” or evolutionary or practical epistemology moves us toward larger Truths. (p. 18)

Pragmatism “... offers a practical and outcome-oriented ...” approach, drawing on a mix of methods that help answer important questions by analyzing and interpreting empirical evidence (Johnson & Onwuegbuzi, 2004, p 17). This logical but

commonsense approach is what I applied to develop the grounded theory (Corbin & Strauss, 2008; Creswell, 2008) presented in Chapter 5.

2.3.2 Lens of Systems Thinking

Concepts of systems thinking align well with a pragmatic perspective, and provided me with a useful analytical framework, allowing me to explain some of the complex phenomena and interactions in our educational system. In this section, I will provide an overview of the systems thinking concept and tools, and will describe the way in which I integrated these into my analyses and conclusions. The materials from which I have drawn definitions and explanations were included in the training manual for the Systems Thinking in Schools training in Portland, Summer, 2006.

Additionally, the materials are available on the Waters Foundation website (Waters Foundation, 2009)

A system is a group of interacting, interrelated, or interdependent elements forming a complex whole, and in almost every situation, there exist sub-systems nested within larger systems. For example, in the case of education, a classroom could be viewed as a system, but clearly, it is nested within the systems of the school, school district, and national educational system. It could also be considered as part of a community system. Because of what can be a nearly infinite level of nesting and complexity, it is necessary to determine the boundaries of a specific system when trying to explain, understand, and improve it. Establishing boundaries defines which elements are required to produce the “behaviors” of the system, eliminating all else (Waters Foundation, 2005).

The structure of a system describes the way its elements are organized and interrelated, and the interdependence and interconnections define the nature and function of a system. Furthermore, for human systems, the structure of the system generates human behaviors we see. Keeping this point in mind, it is important to focus on a system and its structures, rather than blaming individuals for shortcomings. Blaming the individual is common in education. Educating and preparing young people for the world is challenging work, and when efforts do not produce the desired outcomes (e.g., student learning, achievement), people look for explanations. What often results is a blame game—teachers blame students and families, administrators and parents blame teacher, and so on. According to systems thinking, it would be more productive to determine the underlying structures that are causing certain behaviors, then targeting adjustments to the system (Waters Foundation, 2005).

This leads to the concept of leverage. Leverage points are the places in a system where changes can lead to significant, lasting improvements. We find the most leverage in areas where we have some level of control or influence. Nonetheless, a systems thinker also understands that there will always be delays—time lags between actions and their effects. As a result, it is important not to expect or apply quick fixes that do not address underlying problems (Waters Foundation, 2005).

One of the most basic concepts of systems thinking is change over time. Behavior-over-time graphs are tools that can describe the ways that various system structures, functions, and interactions change over time. I utilized change-over-time graphs to help make sense of the student-level data generated for this study. Change-

over-time graphs help to capture trends of one or more variables over time, and when several variables are considered together, it becomes easier to gain deeper, more explicit understanding of the structures and interactions. Another systems thinking concept that relates to change over time is feedback. Feedback describes ways that the effect(s) of actions and interactions “re-enter” the system as a new cause or action. Feedback loops and causal circles are systems thinking tools used to show these interactions (Waters Foundation, 2005).

According to materials provided in the 2006 Systems Thinking in Schools training, a systems thinker embodies several habits. The concepts of systems thinking are nicely summarized by these habits. A systems thinker seeks to understand the big picture. She holds the “tension of paradox and controversy” in mind without trying to resolve it quickly. In other words, she digs deeply in order to surface and test assumptions, to understand and consider the ways in which mental models affect current reality and the future, and she looks at the situation from a new perspective to increase understanding. A systems thinker looks for interdependencies, patterns, and trends, and works to identify complex cause-and-effect relationships. She focuses on structure, not blame, and uses her understanding of system structures to identify possible leverage points. She considers both short- and long-term consequences of actions, notices where unintended consequences emerge, and monitors results, consistently re-aligning actions as needed (Waters Foundation, 2005).

Archetypes are tools used in systems thinking to capture “common stories,” and to help analyze and understand certain phenomena more clearly. Several

archetypes seem relevant in education and environmental science. These archetypes include:

Table 1

Systems Thinking Archetypes, Adapted from Waters Foundation (2009)

Archetype	Brief description
Fixes that backfire or fail	“Quick fixes” often result in unintended consequences, often making the original problem worse
Shifting the burden	When we shift the burden, we apply a symptomatic solution that does not address the fundamental problem. The common result of shifting the burden is that it undermines our ability to fix the underlying problem.
Success to the successful	In a system with limited resources, one party’s initial success justifies devoting more resources to the party, which widens the performance gap between the various parties
Escalation	Escalation is a phenomenon seen in many contexts, and it occurs when one response or action causes a larger effect or response.
Tragedy of the Commons	This is a familiar problem in social and ecological contexts, but essentially, when no part of the system looks out for the well-being of shared resources, eventually those shared resources are

Archetype	Brief description
	degraded or diminished, causing all parts of the system to suffer. This phenomenon, as well as limits to growth, seem critical to our quest for global sustainability.
Limits to growth or success	Any system has a finite set of resources, and when resource limits have been met or exceeded, the system will shift to restore balance. Again, this seems like a critical understanding if we are to solve our global, ecological challenges.

Archetypes are examples of generic structures that have been identified and can be generalized across different situations because the underlying relationships are fundamentally the same. This idea is important for education and educational research, and is what I have attempted to highlight in the grounded theory presented in Chapter 5. By identifying and describing the generic structures in education, it is possible to make generalizations that will help in understanding its complexities, identify leverage points, and make meaningful changes to educational systems.

2.4 Research Design

Taken together, sociocultural and critical theory, pragmatism, and systems thinking provided structure and process for my data analysis and sense-making. As a partner in a grant to transform a struggling, urban middle school into an integrated arts, science and technology magnet, I was an active participant in the school's everyday operations. Based on earlier experiences working at Carver and other local

schools with similar challenges, as well as evidence from the literature, I went into the co-teaching and research experience with an assumption, or a conviction, that students would show higher levels of engagement in science if the curriculum were connected to the students' local environment and community. This evolved to become the principal hypothesis for the research, which may be formulated as follows: connecting learning to meaningful experiences in the local environment can provide culturally accessible points of engagement from which to build enhanced science learning and activities.

A significant portion of the science teaching and learning centered around an environmental education program, River School, operating in the school's watershed. To investigate the ways that students become engaged in and learn science amid the complex interactions that involve and impact students and teachers in the classroom, I utilized a mixed-methods study design that employed an ethnographic approach to build a substantive grounded theory (Corbin & Strauss, 2008; Creswell, 2008). Figure 1 shows the overall research design, which will be discussed further in Chapter 4.

Figure 1. Research design framework

CHAPTER 3 – CONTEXT

Chapter Overview

In this chapter I describe the study's context including school culture and climate, then take a reflective look at the sixth grade science curriculum I co-designed and implemented, describing factors to be synthesized into the grounded theory model presented in Chapter 5. To describe these features of the school, I draw on district data, field notes and reflections, interviews with school administrators, and school artifact. I used these data to reflect upon my experiences at the school and to tell the story based on my interpretations of these experiences.

3.1 Demographic and Achievement Overview

3.1.1 Demographic Profile of Rivergate School District and Carver Magnet School

Several schools in the urban region of northwestern Oregon serve the majority of its low-income and minority populations. These schools tend to be clustered in pockets throughout the region, and fall into several different school districts. George Washington Carver Magnet School (Carver)¹, the site for this study, is located in the Rivergate school district, one of Oregon's largest.

Rivergate School District (RSD) served 46,348 students in the 2006-07 school year. As shown in Table 2, 55% were White, 16% African American, 14% Latino, 11% Asian, 2% Native American and 2% "other." At Carver, the ethnic mix looked considerably different from the district average. At Carver, 26% of the students were White, 46% African American, 18% Latino, 8% Asian and 3% Native American. District-wide, 45% of students were eligible for free or reduced-price lunches; at Carver, 83% were eligible (Rivergate School District, 2006, 2008).

¹ Pseudonyms have been assigned to all schools, districts, teachers, and students mentioned in this study.

Table 2

Ethnicity Data for District and School

Demographic Breakdown	Rivergate School District	G.W. Carver School
African American	16	46
European American	55	26
Latino	14	18
Asian	11	8
Native American	2	2
Free/Reduced Lunch	45	83

3.1.2 Achievement Profiles for Rivergate District and Carver School in Reading and

Math

As with most urban districts across the nation, Rivergate had a pronounced achievement gap between minority and low-income students on the one hand, and their White, middle-class peers on the other. At the eighth-grade level, there was a 30% difference in achievement level between White students and their African American and Latino classmates in both reading and math, measured from the 2004-05 school year through the 2006-07 school year. Fewer than 60% of African American and Latino students met or exceeded benchmarks in reading and math during this three-year period.

There were notable differences in the achievement levels and gaps at Carver compared with the district overall in reading and math, and some interesting trends for the three years between 2004-05 and 2006-07 (the year of the co-teaching/research

experience). At Carver, achievement gaps between White students and African American and Latino students were not as large as gaps district-wide. However, this was due to White students performing at levels lower than district averages, as much as it was due to minority students performing better, as shown in Tables 3 and 4 (Rivergate School District, 2006, 2008, 2009).

Table 3

Percentage of Eighth Grade Students in Rivergate School District and George Washington Carver Magnet School Meeting or Exceeding Benchmark in Reading

	% Meeting or Exceeding Benchmark					
	2004-05		2005-06		2006-07	
	District	Carver	District	Carver	District	Carver
White	78	54	82	56	83	48
African American	46	50	51	40	55	48
Latino	42	39	48	26	53	54

Test results in reading from the 2006-07 school year, presented in Table 3, show virtually no achievement gap at Carver between White students and African American and Latino students; but achievement among White students remained low, with around 50% meeting or exceeding benchmarks. Results in math, shown in Table 4, similarly show White students at Carver performing well below the district average. At Carver, test scores of African American and Latino students mostly improved, resulting in no achievement gap between White students and students of color by the 2006-07 school year (Rivergate School District, 2006, 2008, 2009).

Table 4

Percentage of Eighth Grade Students in Rivergate School District and George Washington Carver Magnet School Meeting or Exceeding Benchmark in Math

	% Meeting or Exceeding Benchmark					
	2004-05		2005-06		2006-07	
	District	Carver	District	Carver	District	Carver
White	78	54	80	65	83	55
African American	43	28	47	37	53	55
Latino	47	45	51	44	56	56

3.1.3 Achievement Profile for Rivergate District and Carver School in Science

The District's achievement gap in science was even more pronounced, with differences of 40% or more in achievement level between White and minority students, as shown in Table 5. The proportion of African American and Latino students meeting or exceeding benchmarks in science was consistently 40% or more below the percentage of White students meeting or exceeding benchmarks. At Carver, however, the achievement levels of White students were lower than the district average, and in fact, in 2007-08 they were lower than those for African American and Latino students at the school and in the district (Rivergate School District, 2006, 2008, 2009).

Table 5

Percentage of Eighth Grade Students in Rivergate School District and George Washington Carver Magnet School Meeting or Exceeding Benchmark in Science

	% Meeting or Exceeding Benchmark							
	2003-04		2004-05		2005-06		2007-08 ²	
	District	Carver	District	Carver	District	Carver	District	Carver
White	69	41	77	55	81	65	82	34
African American	23	12	34	18	39	24	40	41
Latino	27	22	35	24	44	17	45	46
Asian American	54	55	67	83	74	93	69	80
Native American	35	N/A	55	N/A	61	N/A	50	N/A

In the 2003-04 school year at Carver, 41% of White students met or exceeded standards in science, while only 12% of African American students and 22% of Latino students met or exceeded standards. In the 2004-05 school year, 55% of White students met or exceeded standards in science compared with 18% and 24% of African American and Latino students, respectively. In 2005-06 the percentage of White students meeting or exceeding standards rose to 65%, while the percentage of African American students rose only to 24% and the percentage of Latino students actually dropped to 17%. Due to problems with the state's electronic testing system, in the 2006-07 school year Rivergate eighth-graders did not take the science knowledge and skills tests normally administered at year's end. Results for the 2007-08 school year

² Note: Due to problems with the statewide electronic testing system, the science knowledge and skills tests were not administered in the 2006-07 school year.

are reported, but the time gap from the missing data makes the results difficult to analyze, including the anomalous drop in test scores among White students. Change in science achievement levels over the four years at Carver are shown in Figure 2. With the exception of Asian American students, performance among all ethnicities was low.

Figure 2. Science achievement at George Washington Carver Magnet School from 2003-04 through 2007-08.

The data presented to this point, describing basic achievement patterns in the Rivergate School District and at Carver School, raise questions about the factors influencing these trends. Clearly, there were consistent achievement gaps in all subjects district-wide between White students and African American and Latino students; and there were similar gaps between Carver minorities and district-wide Whites; but what factors contributed to the closing of gaps at Carver, notably among Latinos in reading and African Americans in math? Was this a trend that continued, was it an anomaly, or was it a short-term gain from innovative practices introduced through the magnet program? Although the answers to these questions are beyond the

scope of this study, the patterns and trends seen in the data were of interest as they can be related to the culture and climate of the school. Achievement results were significant in school culture, particularly due to potential consequences for not making “Adequate Yearly Progress” as defined in the No Child Left Behind Act. Persistently low achievement results at Carver influenced perceptions about the school, both internally and externally; one goal of the magnet program was to begin changing these perceptions through a process of transformational change at Carver. Whether or not improvements in the achievement data resulted directly from magnet activities, by 2007-08, the efforts of teachers and administrators were beginning to change attitudes and perceptions among students, parents, and the community.

3.2 Researcher’s Experience of Carver Culture and Climate

Carver already had its own culture before the magnet program began or Center for Science Education graduate students and faculty became involved. What I experienced may have been a culture in transition; but here, from field notes, school artifacts, and personal reflections from teaching, are descriptions of the school’s culture and climate as I perceived them; that is, from the standpoint of a program partner and researcher.

As mentioned above, Carver was a school plagued by historic patterns of low achievement as measured by standardized tests, as well as negative perceptions in the school and community, low parental involvement, high disciplinary rates, and high staff turnover. The intention of the magnet program as eloquently reflected in the school’s mission statement—“Designing a better future ... for ourselves, our

community, our world”—was to help students, teachers, and administrators lead the process of transformational change. From the standpoint of teaching and leadership, two primary foci that helped drive and guide the process were systems thinking and cultural competence. Instructionally, the focus of the magnet program was teaching through inquiry-based methods, and infusing the arts and technology into learning. I will discuss systems thinking and cultural competence as they related to the dynamics of the school, followed by a reflection on teaching in the sixth grade science classes.

3.2.1 Systems Thinking at Carver Magnet School

Important to Carver Magnet School’s teaching culture was the fact that the assistant principal, Molly Sharp, was a national leader of the Systems Thinking in Schools initiative of the Waters Foundation (incorporated, not coincidentally, into my research model). Because of Sharp’s involvement, many Carver teachers became familiar with systems thinking concepts, and these were routinely incorporated into staff meetings and professional development offerings throughout the year. Many teachers participated in a weeklong summer course in 2006 on systems thinking concepts and applications in school. Sharp was a driving force for change in the school.

A central point that Assistant Principal Sharp emphasized to her teachers (and to me as teacher/researcher) was one of patience and perseverance, in a systems thinking guise. In Chapter 2 I described systems thinking concepts and tools; relevant here are the concepts of change over time, feedback loops, and structure that generates behavior. Attitudes and perceptions—among teachers, students, administrators, and

the public—change over time in response to system-level structures, practices, and organization. Alas, these changes can be negative, and such was often the case at Carver, as a result of perceived continual failure of the system to provide educational success to young people. Knowing that behavior patterns emerge from systems and their organizational structures, the systems thinker focuses on structures, rather than blaming individuals. Sharp encouraged teachers to focus on correcting systems, rather than blaming individuals, thus working to avoid destructive feedback loops. The interdependent nature of components in an educational system such as Carver can cause feedback effects, as when negative attitudes and the manifesting behaviors reinforce and further increase negative attitudes and beliefs—about students, teaching and learning, even schooling in general. In the matter of student achievement, low belief in students’ abilities can lead to lower performance, reinforcing lowered attitudes and expectations, working in a downward spiral.

As described in Chapter 2, for the systems thinker, in order to make decisions that are positive and effective, system boundaries must be established. By establishing system boundaries, leverage points—the places in the system where innovations and interventions will have the greatest positive impact—can be identified. In implementing innovations and interventions, there will be time delays between actions and outcomes and effects of those actions.

Assistant Principal Sharp, Carver teachers, and CSE partners (including myself) were aware of this feature of educational systems, but struggled against day-to-day realities. To ensure sustainability of promising innovations, system structures

must be redesigned for long-term success. Unfortunately, with educational innovations funded by grants lasting from three to five years, and with too-frequent turnover in personnel, this often does not happen. Individuals in a school—actors within a system—can revert to existing patterns and behaviors after initial funding ends or innovators depart. These were particular challenges at Carver, as revealed in Figure 3, showing changes in leadership and program initiatives over the past ten years.

Final year of Urban Ecosystems Project; 21st Century Community Learning Centers Initiative; Established SUN School program					Magnet grant awarded	Began partnership work	Year of co-teaching; Final year of magnet grant		
99-00	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09
			New Principal (interim)	New Principal	Summer institute on Cultural proficiency		Daily team planning time incorporated into school schedule	Assistant Principal left district	Principal moved to high school (interim principal at Carver)

Figure 3. Timeline showing changes in leadership and program initiatives.

3.2.2 Preparation for Teaching: Cultural Training

During the Urban Ecosystems Project and the 21st Century Community Learning Centers initiative, noted in Figure 3, faculty and graduate students from the

Center for Science Education (CSE) worked at Carver. These interactions provided a level of mutual familiarity when the magnet partnership was established in 2005. Between 1999 and 2006, numerous teachers left Carver, but a core group of approximately ten remained.

When I came to Carver in 2005, at the beginning of the partnership, but midway through the magnet grant, I had worked there through other grant-funded projects but had never been intensely involved at the school. Previously I had supported other PSU faculty, staff and graduate students, while the main focus of my work had been at other schools (notably Lakeview, another struggling middle school that ultimately closed due to persistent internal and external problems, including achievement). Nonetheless, through the previous support work I had established a slight presence at the school and was not a completely unfamiliar face, while staff at the school were also familiar with my colleagues from CSE.

When the district was first awarded the magnet grant, the schools involved were not ready to implement its goals. Our CSE team worked to position ourselves as resources for the school, but getting started took a while. During the 2005-06 school year, I supported one classroom teacher who was teaching math, science, and music. As a result, he had less planning time than other teachers, and a challenging group of eighth graders as well. Working with this teacher allowed me to develop further the partnership and to begin assimilating into the school culture. By the end of 2005-06, the formal partnership agreement had been established, so teachers, administration,

and staff at the school had come to view our CSE team (i.e., myself and three other graduate students) as resources for implementing school goals.

Although CSE graduate students were viewed as resources, it was not until a weeklong summer institute on cultural proficiency that we became more fully assimilated into the school culture. I describe the institute in some detail here, because it represented the beginning of my work, revealed much about school climate, and directly influenced this research.

Valerie Evans, a National Science Foundation contractor for multicultural education, led the summer institute, facilitating group learning around difficult topics of race, culture, learning, and equity. Participation helped CSE graduate students assimilate into the school community and culture (and contributed to my own professional development, translating research into practice). Combination of Evans' cultural training with Vice Principal Molly Sharp's systems thinking tools made the summer institute an inspirational experience. The entire staff of Carver participated, and showed willingness to take a deep look at their own values, beliefs, and habits, as well as to begin changing in ways that would best support students' school experiences. This was not easy or comfortable work, but all committed to a degree I had not seen previously from staff. A copy of the weeklong agenda from the summer institute is included in Appendix A.

The principal of the school, James Monroe, participated alongside teachers. He and Molly Sharp made a good team, with positive personalities that encouraged cooperation from staff and complementary work styles. Mr. Monroe was a bit like a

Southern preacher, rallying and motivating staff around the notion of deep responsibility and commitment to give kids the very best. Molly Sharp was strategic, personable, and very effective, displaying a thorough understanding of the ways people and systems operate. Together they made an effective leadership team.

Each hour and day of the institute was well planned and well facilitated to help staff gain deeper insights and grow personally and professionally. Each day consisted of fun activities that also provided some type of profound lesson. Most of the lessons helped participants uncover personal assumptions and biases, or see the hidden norms and rules of mainstream culture. One concept that Evans discussed—one that I came to internalize—was that of students who are “school dependent,” relying on school as their primary source not only of education but of socialization—i.e., socialization into mainstream culture. She compared mainstream children who grow up with hundreds of books in their homes to children who come to school not having read or been read to more than a handful of times, if at all (Debrief from Professional Learning Community Institute, 8/21-25/06). This concept stresses a point (which I regularly ponder): equal does not always mean the same, and fair is not necessarily equal.

Each day, Evans reminded staff of their (our) commitment to stay dedicated to the school’s vision and goals, and to be willing to adjust as new data become available, but always to work toward the ultimate goal of improving learning for ALL students. She spoke of social inequity and system change, saying that for the latter, participants must have clarity, coherence, consistency and commitment. She introduced the CBAM (Concerns-Based Adoption Model), with its basis in the idea

that change is developmental, i.e., change does not happen because of a decision to make it, but takes ongoing work, reflection, and commitment (Debrief from Professional Learning Community Institute – 8/21-25/06).

The staff displayed and expressed commitment during the week of the institute; to a large degree that commitment lasted through the year. Nonetheless, as the school year got underway, all were quickly swept into the common mode of crisis management and short-term, survival-oriented planning. Work at Carver always felt like swimming upstream, trying to stay afloat.

(One regret was that I did not work more closely with the sixth grade teaching team, establishing goals and planning lessons. Much of the institute consisted of working in teams, but since I participated as science facilitator and partnership coordinator for the grant, I worked mostly with K-5 teachers. It was important and useful, but limiting.)

3.2.3 Sixth Grade Science—Theory and Practice

My teaching employed models promoted by the Center for Science Education (CSE), the mission of which is to enhance science teaching and learning through innovative education, research, and community outreach. Through its programs, CSE aims to help students and teachers raise their capacity to participate in the community as informed, thinking citizens.

CSE promotes a constructivist model of science education that uses technology, including computers and technical instruments, as a powerful tool to enhance science inquiry. In this model, teachers build learning activities around

students' existing knowledge, skills, and interests, and use the local environment—neighborhood and urban locales—as context for integrating curriculum, and as a way of engaging students in meaningful, real-world learning opportunities. Students design and implement inquiries that are of personal or social significance, using their own social and cultural “capital” in meaningful ways.

Technology supports students' research projects, providing tools to help them critically review and analyze large amounts of data, then share findings publicly. Throughout the inquiry process, formative assessment strategies provide real-time information measuring student understanding, and providing guidance for adjusting instructional strategies. Reflective, formative assessments not only provide feedback on student work, but also help students develop metacognitive skills, becoming more self-regulated and in control of their learning.

This was the model of learning and teaching that I envisioned for my co-teaching work; on implementation, it fell short. Despite challenges in many forms, our sixth grade science team worked together to help students learn about inquiry-based science, their local environment, and varied science content. Four main inquiry projects were introduced over the course of the year, one of which featured projects for the school science fair. In addition to the full inquiry projects, the team involved students in numerous hands-on and lab-based activities in which students learned the inquiry process. Teaching focused on helping students learn basics of experimental design, development of hypotheses, and analysis of data. Classes also participated in a local environmental education program called River School, which included

classroom visits from the River School educator and four field trips. Participation in River School was used as a means to engage students in science and help them understand connections to their local environment. The students also went to Outdoor School for a week in the fall and participated in a number of garden-related activities throughout the school year.

A visual map of the intended curriculum, showing planned activities and curricular connections over the span of the school year, is presented in Appendix B, along with key concepts of the curriculum, sample lesson plans, quizzes, and an example of a student scoring guide. An overview of the River School lessons, with connections to science standards, as well as the schedule of classes and field trips is included in Appendix C.

Although my preparation for the classroom followed an alternate route relative to what most teacher education programs provide, as a first year teacher I was equipped with a strong understanding of multicultural education, learning, and science education, as well as experience working with teachers and students in classroom and field settings. Furthermore, my background in science provided me with a strong foundation of content knowledge. Nonetheless, classroom realities made implementing research-based practices challenging. Many factors contributed, ranging from student issues, scheduling logistics, interruptions, and lack of time for certain activities, to personal assumptions and habits and, sometimes, district decisions impacting classroom activities. These issues will be discussed in greater detail in Chapter 6.

3.3 Summary

In this chapter, I have presented an achievement profile of George Washington Carver Magnet School, briefly described the culture and climate of the school, reviewed a key contextualizing event—a cultural sensitivity training—and described the sixth grade science curriculum that I set out to use in my role as teacher/researcher, along with comments about the way it played out in the classroom. The purpose of this chapter was to describe the context of the teaching and researching experience. These contextual factors also provided insights that were useful in developing the grounded theory model presented in Chapter 5.

CHAPTER 4 – METHODS, PROCEDURES AND ANALYSES

Chapter Overview

This chapter outlines the methods used to investigate ways that students become engaged in and learn science. It includes a review of methodological and philosophical perspectives, as well as a more detailed description of the research design. In addition, the chapter provides an in-depth explanation of the process and procedures used for analysis and describes how the findings will be organized.

4.1 Research Design

This research was developed from a school-university partnership funded by a magnet grant from the U.S. Department of Education. The district was awarded funds to transform a high school, middle school, and four elementary schools into an integrated and articulated arts, science, and technology magnet program. The school in this study was the middle school, which the district converted to a K-8 model immediately before the year of the study, 2006-07. As both researcher and co-teacher, I was a participant observer engaged with teachers and administrators as they worked to transform a struggling urban middle school into a model for student success.

Through the school-university partnership I co-taught three sixth-grade science classes, one with the sixth grade math teacher (third period) and two with one of the sixth grade language arts/social studies teachers (fourth and fifth periods). I worked both individually and collaboratively with the sixth grade team to implement an inquiry-driven, project-based science curriculum involving deliberate connections to the students' local physical environment. As stated in Chapter 2, based on prior experiences working with teachers and students at Carver and other high-minority and

high-poverty schools in the district, as well as evidence from existing research literature, I went into this experience with the assumption and conviction that generated my central hypothesis: that connecting learning to meaningful experiences in the local environment could provide culturally accessible points of engagement from which to build enhanced science learning and activities. This study tested that hypothesis.

The research took a pragmatic approach, aimed at addressing shortcomings in goals within the district and beyond for scientific literacy. The study employed mixed methods in order to build a deeper understanding of the complex interactions that take place in science classrooms. Student-level data were the primary focus of study and provided insights and examples of complex phenomena relating to students' engagement, thinking and learning in science. These data were synthesized with themes from focus groups and the literature to build a grounded theory that helps explain these complex phenomena. Theory building followed a process of open, axial, and theoretical coding, adapted from similar processes described by Corbin and Strauss (2008) and Creswell (2008) (described further in Section 4.1.3.1).

The phases in the overall research design were presented in Figure 1. These phases incorporated the steps involved in building a grounded theory, as adapted from Corbin and Strauss (2008) and Creswell (2008). The first phase included a process of open and axial coding (Corbin & Strauss, 2008; Creswell, 2008), in which I identified and organized key words and concepts, resulting in an initial framework that guided the descriptive analyses. The descriptive phase of the study involved an in-depth

analysis of student-level data in search of insights into students' levels of engagement, thinking and learning in science. In the final phase of theory generation, I integrated the complex phenomena related to learning and teaching science, teased out of the student-level data (work files and focus group interviews), with field notes and other interview data, to converge on a final model. The data sources and methods used in each phase of analysis are summarized in Table 6.

Table 6

Data Sources for Study

Primary Data – Methods of Analysis – Phase of Research			
Data	Description	Methods of Analysis	Primary Phase(s) of Analysis
Student files	Work samples, journal entries, "quick-writes," tests/quizzes (including bonus questions)	Look for changes in thinking and learning over time; open and axial coding; constant comparison and questioning strategies; (modified from Creswell, 2008 and Corbin & Strauss, 2008)	Descriptive phase and Grounded theory generation
Focus groups	Four different groups with 20 students total	Open and axial coding; constant comparison and questioning strategies; (modified from Creswell, 2008 and Corbin & Strauss, 2008)	Grounded Theory generation
District Data	Student achievement data; school statistics/demographics, school organization (middle school to K-8)	Description of school demographics, achievement, mandates, changes over time; Compare this school to others	Description of School
Field Notes	Classroom experiences, professional development and school activities	Open and axial coding; constant comparison and questioning strategies; (modified from Creswell, 2008 and Corbin & Strauss, 2008)	Analysis of science curriculum and Grounded Theory generation
Interviews	Principal & Vice Principal - Spring, 2007	Ethnographic descriptions (Creswell, 2008)	Description of School
	Teachers – January-June, 2007		
Reflective writings	Several throughout the year – both classroom teaching reflections as well as reflections on school climate/culture	Open and axial coding; constant comparison and questioning strategies; (modified from Creswell, 2008 and Corbin & Strauss, 2008)	Grounded Theory generation
Planning and lesson calendar	Amount of change and adaptation required to get through day, week, month	Case study description (Creswell, 2008)	Analysis of science curriculum

4.2 Participants

I invited all students (approximately 85) in three sixth-grade science classrooms at George Washington Carver Magnet School to participate in the research; of these, 37 returned informed consent forms. Although as a group, the self-selected participants displayed the same range of characteristics—ethnicities, genders, challenges, interests, experiences, socio-cultural backgrounds, and conceptions of science—found in the student body as a whole, the cohort differed in important ways. In particular, African American males were under-represented (10.8% of the cohort vs. 24.4% of the school), while both male and female White students were over-represented (16.2% and 18.9%, respectively, vs. 11.0% and 13.4% in the school as a whole). Informed-consent return data are shown in Table 7.

Table 7

Composition of Sixth Grade Cohort—Ethnicity; 2006-07

		Whole group		Cohort	
		Number	%	Number	%
Asian	Male	4	4.9	1	2.7
	Female	3	3.7	2	5.4
Black	Male	20	24.4	4	10.8
	Female	17	20.7	8	21.7
Latina	Male	6	7.3	3	8.1
	Female	8	9.8	4	10.8
Native American	Male	2	2.4	2	5.4
	Female	2	2.4	0	0.0
White	Male	9	11.0	6	16.2
	Female	11	13.4	7	18.9
Total		82	100.0	37	100.0

Also notable was that Talented and Gifted students were over-represented (16.2% vs. 9.8%) while students with Special Education needs were under-represented (18.9% vs. 24.4% in the school), as shown in Table 8.

Table 8

Composition of Sixth Grade Cohort—Learning Groupings; 2006-07

	Whole group		Cohort	
	<i>Number</i>	<i>%</i>	<i>Number</i>	<i>%</i>
ESL	9	11.0	3	8.1
SPED	20	24.4	7	18.9
TAG	8	9.8	6	16.2

4.3 Data Collection

In my role as teacher/researcher, I collected schoolwork from the 37 participating students over the course of the 2006-07 school year, which served as the primary source for analysis. I maintained a portfolio of work for each student that included lab reports and science inquiry papers, journals and quick-writes, worksheets, quizzes, and diagrams. Before the last day of school, I made copies of the contents of participating students' files and returned their original work.

In addition to this thorough scrutiny of student work, I and another graduate researcher conducted four student focus group interviews involving 20 of the participating sixth graders. The graduate researcher also interviewed the language-

arts/social studies teacher with whom I co-taught and me as the co-teacher, about aspects of the science curriculum, particularly the field-based components.

I kept records and artifacts from the school relating to magnet activities and to school structures, activities, attitudes, and personnel. To capture the experience of co-teaching sixth grade science, I maintained field notes and reflective writings as well as all lessons, planning documents and curricular information.

Prior to analysis, I organized all data collected over the year, sorting and organizing by topic and relevance and noting data that seemed especially significant. This initial sort resulted in three broad divisions: data describing the culture and climate of the school; data describing sixth grade science teaching and learning at the school; and the student-level data revealing information about students' experience and progress. A brief description of the culture and climate of the school and sixth grade science classes was presented in Chapter 3; student-level data, the primary focus of analysis, will be presented next. Analysis procedures are described in the remainder of this chapter; results will be presented in Chapter 5.

4.4 Data Analysis

4.4.1 Phase One of Grounded Theory

To start the grounded theory analysis, I extracted potentially interesting quotes or pieces of work from each student's file and organized them into Excel spreadsheets, one for each student, including dates and assignments from which the quotes were drawn. I methodically analyzed 6 of the 37 student files, using an open coding process that included constant comparison, memo writing, and question asking, similar to that

described by Corbin and Strauss (2008). From the open coding process, I identified key words and themes representing phenomena that appeared to be taking place. Examples of the themes identified are “adolescent development,” “middle school drama,” “challenges with writing,” “own ideas vs. shared ideas,” “behavior management,” “personal connections,” and “student language vs. science language.”

Using an axial coding process for these early stages of theoretical coding (Corbin & Strauss, 2008), I began organizing themes identified from student work, along with concepts from the literature, to provide an initial analytical framework. Themes and concepts were grouped into three categories: science education, culture and language, and adolescent development.

In agreement with findings from the literature (Norman et al., 2001), the phenomena observed in student and classroom data revealed a tension between the mainstream culture of school and science and the cultures that students brought to the classroom. A model was developed representing this tension; it is included in Chapter 5 (see Figure 13). After this initial phase of analysis, following grounded theory practice, I considered whether the process was logical and effective, and determining that it was, proceeded with the next phase of analysis, the descriptive study.

4.4.2 Descriptive Phase of Study

In the descriptive phase, I analyzed student-level data to investigate whether and how students were engaged in science, and whether their levels of thinking and learning changed over the course of the year. I compared the cohort as a whole against

different subsets selected by class period and ethnicity. An overview of data analyzed for each measure or indicator is presented in Table 9.

Table 9

Data Measures and Indicators

Measure	Data Sources
Engagement	<ul style="list-style-type: none"> Field trips attended Work completion rates
Thinking	<ul style="list-style-type: none"> Questions, hypotheses, analyses and conclusions from science inquiry work samples Answers to selected quiz questions, journal prompts and daily work
Learning	<ul style="list-style-type: none"> Work sample scores

4.4.2.1 Engagement

The key measure chosen to gauge students' level of engagement in the science curriculum was attendance rate on field trips. One of the most significant components of the science curriculum was involving students in a local watershed education program. As part of the program (River School), the watershed educator came to class and provided lessons, approximately twice each month. Lessons covered topics including watersheds, water cycle, water quality, macroinvertebrates, and ethnobotany. A summary of River School lessons and curricular connections is provided in Appendix C. In addition to these lessons, students participated in three field trips associated with the classroom visits. On the first trip in the fall, students

studied a local watershed and conducted water quality testing. On the second field trip in the winter, students planted native trees and shrubs. For the spring trip, students collected macroinvertebrates and learned how the organisms can be used as indicators of water quality. Finally, near the end of the year, most of the students were invited to participate in a culminating field trip, canoeing in the slough near their field site.

I analyzed field trip attendance data from the entire sixth grade class in order to describe differences between the cohort and other students. For the cohort, I also compared attendance rates among different ethnic groups and among the three class periods.

In addition to field trip attendance rates, I used students' rate of work completion as an indicator of engagement. For these analyses, I compared completion rates for the cohort to completion rates by ethnic group and class period.

4.4.2.2 Thinking

The next set of analyses was to help determine how students' level of thinking changed over time. I extracted from three lab reports (work samples) the questions, hypotheses, analyses, and conclusions that students developed, as well as responses to particular quiz questions, journal prompts, and "quick-writes" (an exercise format).

The three work samples included:

- Lab with brine shrimp—investigating the abiotic factor of salt in relation to brine shrimp survival;
- Heart rate lab and district anchor assignment—investigating ways that different exercises affect heart rate; and

- Student-generated science inquiry—in which most students utilized Vernier equipment to help with their investigations.

Since I was also involved with the students as their teacher, it was important to bring a level of objectivity to this portion of analysis. To some degree, the time gap of two years between teaching and data analysis provided a level of objectivity; however personal biases were further reduced by the procedures employed. After all the quotes were compiled into an Excel spreadsheet, each quote was assigned a numeric code, referencing the student who wrote the words, as well as the time of year (e.g. 4011 – was student 401 during the first trimester), and randomized before analysis.

In all I analyzed 941 quotes, at least some from each of the 37 participating students, using a four-point “Thinking Rubric” (scale) on which One represented low-level thinking; Two, medium-low thinking; Three, medium-high level thinking; and Four, high-level thinking. In developing the Thinking Rubric, I used elements from Bloom’s taxonomy and level-of-thinking measures, which are based on cognitive complexity of tasks (Krathwohl, 2002; Webb, 2005). The Thinking Rubric, presented in Appendix D, includes information describing the qualities and characteristics of each level of thinking.

To ensure internal consistency in scoring, duplicate quotes were intentionally included when students had turned in multiple drafts of an assignment. These duplicates were randomized with all the quotes for analysis. Including duplicates, I rated 941 student quotes. After scoring all quotes, I sorted them by student codes (e.g., 4011) to compare consistency among duplicates. When differences occurred, quotes

were re-analyzed using the Thinking Rubric, to determine the final score. Before tallying the final results, duplicate scores were deleted so results were not skewed high or low from multiple examples of the same student words. Of 186 duplicate quotes, only 16 required re-scoring, resulting in a 91% rate of internal consistency, corrected to 100%. In several instances, students dramatically changed their words from one draft to the next. When this resulted in a legitimately higher score, both were included in the final analysis.

To further ensure internal consistency I sorted quotes by time of year and compared the ways that students worded the same teacher-generated questions at different times of year. For the brine shrimp lab, no matter how students worded the question in their final papers, the inquiry question itself was only level Two in the Rubric, leading to implications for teaching (see Chapter Six for discussion). For the heart rate anchor paper, however, students' choices of wording may have impacted the final scores, which ranged between level Two and level Three. I further ensured consistency by making sure similar answers on quiz questions were scored using the same degree of scrutiny.

After completing these internal quality assurance procedures, 732 quotes remained for analysis. I determined the frequency of each level of thinking; then calculated the percentage of medium-high and high-level responses within each subgroup (i.e., class period, ethnic group). Using the concept of change over time, I compared the percentage of medium-high and high-level responses for each trimester, by class period and ethnicity, to show changes in students' levels of thinking.

4.4.2.3 Learning

To measure students' learning over the course of the year, I analyzed students' scores on the three primary science inquiry work samples—the brine shrimp lab, the heart rate anchor assignment, and the open-ended science inquiry. In each trimester, students completed an investigation and were required to write a paper sharing their work. These assignments were intended to help students learn about inquiry and to develop process and thinking skills.

Due to my role as the students' science teacher, it became clear that I tended to score students' work samples with increasing expectations over the course of the year. As a result, it was necessary to rescore the three science inquiry work samples after the research period had ended in order to provide a consistent evaluation of students' work over time. To do this, a group of graduate students rescored each work sample, using the Oregon Department of Education's Science Inquiry Scoring Guide. This document provides guidelines for scoring four aspects or "strands" of student work: Forming a Question or Hypothesis; Designing and Investigation; Collecting and Presenting Data; and Analyzing and Interpreting Results. Students can earn up to six points in each strand; four points are considered "meeting benchmark." The graduate students calibrated their scoring process to ensure an inter-rater reliability of over 90%. A copy of the Oregon Science Inquiry Scoring Guide is provided in Appendix E.

After the work samples were rescored, results were compiled into an Excel spreadsheet. Using the software's analysis tool package I calculated median scores,

then analyzed these to develop change-over-time comparisons by class period and ethnicity.

4.4.2.4 Profiles

To gain a deeper understanding of the interactions among student engagement, thinking, and learning in science, I organized results for each subgroup, i.e., class period and ethnicity, into group profiles that included the three change-over-time graphs: field trip attendance, level of thinking, and work sample scores. These group profiles provided a summary of students' engagement, thinking, and learning, and were used as a source of insight in grounded theory generation.

4.5 Developing the Grounded Theory

By synthesizing all findings—evidence of student engagement, thinking, and learning in science; description of the school culture and climate; description of the sixth grade teaching and learning experience—with concepts from the literature, I developed the grounded theory model to represent the complexities of teaching and learning. In developing this model, I incorporated systems thinking concepts and tools in order to identify and explain interactions and interconnections among students and teachers and the schools in which they are situated. This model is intended to help understand the interconnecting phenomena, while still capturing the complexity of the system.

Few systems are as complex as education. Each individual student could be considered a system. Compound that individual complexity to the level of an entire classroom, school, or ultimately a city's or state's educational system, and the tasks of

sense-making and decision-making become challenging. This grounded theory model should make it easier to identify leverage points where actions and interventions could have the greatest impacts.

CHAPTER 5 – FINDINGS

Chapter Overview

The central questions addressed in this study are:

- *Do students engage in science, and if so, how do they engage?*
 - *Do students' levels of thinking and learning change over the course of the year, and if so, how?*
 - *What factors interact with and impact student engagement, thinking, and learning?*

This chapter presents results from the mixed-methods study. In the first section are results from the descriptive study—student engagement, thinking, and learning, in that order, which are next summarized into group profiles showing possible connections and interactions. Remaining sections discuss phenomena observed in student- and classroom-level data, describing interconnections and leading to the grounded theory model.

5.1 Descriptive Study

5.1.1 Evidence of Engagement

Field trip attendance rates and percentage of work completed over the course of the year were the two main indicators used for assessing student engagement. For work completion, the percentage is expressed as a total value for the year; for field trip attendance, as well as for the remaining analyses presented in this section, findings are presented in change-over-time graphs, a fundamental tool and concept in systems thinking.

5.1.1.1 Work Completion Analyses

I maintained a work folder for each student that included every item of work that s/he completed, making it easy to calculate work completion percentage. Mean percentages and standard deviations were calculated for the cohort and for the two

subgroupings, class period, and ethnicity. These values were used as an indicator of students' level of engagement in science learning activities.

5.1.1.1.1 By class period.

Overall percentages of work completed by the cohort together with percentages for each class period are shown in Table 10. As indicated by the large standard deviations, the percentages of work completed varied widely. Students in third period completed substantially less work than students in the other two periods, pointing to a difference in their levels of engagement and participation.

Table 10

Percentage of Work Completed by Class Period

	% Work Complete	<i>n</i>	Standard Deviation
Cohort	64.5	37	15.06
3 rd Period	56.6	15	12.97
4 th Period	71.1	12	17.69
5 th Period	68.5	10	9.16

5.1.1.1.2 By ethnicity.

Percentages of work completed for each ethnic group are shown in Table 11. Although some of the groups were rather small, these results show that other than the Asian American students, work completion rates were similar among ethnic groups.

These findings provide evidence of differences among students in the three class periods; using the measure of work completion, it seems that class period had more influence on students' level of engagement than did ethnicity.

Table 11

Percentage of Work Completed by Ethnicity.

	% Work Completed	<i>n</i>	Standard Deviation
Cohort	64.5	37	15.06
African American	63.8	12	14.02
Asian American	77.5	3	12.92
Latino	63.8	7	14.22
Native American	66.8	2	3.12
White	62.4	13	17.93

5.1.1.2 Field Trip Attendance Analyses

Analysis of field trip attendance showed interesting trends for student participation in field-based learning activities. Local and field-based aspects of the River School were predicted to be effective engagement strategies for students; however, this proved not always to be the case.

5.1.1.2.1 By informed consent – cohort vs. non-cohort.

The field trip attendance rate of the cohort was compared to the attendance rate of the entire sixth grade class to provide a deeper understanding of differences between the cohort and non-participating students. The decision to do this was based on an observation that participation rates and levels of engagement might be different between the cohort students and the students not participating in the research study. Of 81 students in sixth grade science, 37 comprised the study cohort. On average, the

cohort's attendance on field trips was consistently and substantially higher than the non-cohort students as shown in Table 12.

Table 12

Percentage of Students Attending Field Trips by Informed Consent

	Canoe			
	Trip #1-Nov	Trip #2-Feb	Trip #3-Apr	Trip-May
Cohort ($n = 37$)	89	73	87	81
Non Cohort Group ($n = 44$)	68	64	64	61
Total Attendance ($n = 81$)	78	68	74	70

These results are also shown as a change-over-time graph in Figure 4. In addition to showing that the percentage of students attending field trips was consistently lower among the non-consent (non-participating) group than the consent group, the change-over-time graph also shows that the field trip attendance rate among the non-consent group remained relatively consistent (ranging between 61% and 68% attendance), while the attendance rate for the consent group varied more over the course of the year (ranging from 73% to nearly 90% attendance).

Figure 4. Percentage of students attending field trips by informed consent.

In the remainder of this analysis, I compare field trip attendance rates for the cohort as a whole with those for the two subgroupings, by class period and ethnicity. Although I do not present additional results for the non-participating students, the general trends shown in the cohort/non-cohort comparison above were consistent with my observations as a teacher throughout the year.

5.1.1.2.2 By class period.

Field trip attendance rates for the cohort and for three class periods are shown in Table 13. With the exception of the third field trip, the third period's attendance was considerably lower than that for the other two periods and for the cohort overall. On the first field trip, there was a relatively small difference of 10% in attendance between the third period and the cohort overall. Comparing the three class periods' attendance rates, there was a 21% difference in attendance on the first field trip

between the third and fourth period classes, while the difference between the third and fifth period classes was 11%, similar to that between the third period and the cohort overall. These gaps widen on the second field trip, with a 30% difference in attendance between the third period and the cohort, and more than 45% between the third period and the other two classes.

Table 13

Percentage of Students Attending Field Trips by Class Period

	Canoe			
	Trip #1-Nov	Trip #2-Feb	Trip #3-Apr	Trip-May
Cohort ($n = 37$)	89	73	87	81
3rd Period ($n = 14$)	79	43	93	64
4th Period ($n = 13$)	100	92	85	92
5th Period ($n = 10$)	90	90	80	90

On the third field trip, attendance rates for the third period and the other periods are much closer; in fact, third period attendance on this trip was slightly higher than that for the fourth and fifth periods. A possible explanation for this anomalous result was that students were told they had to attend at least one other field trip to participate in the final canoe trip. This expectation probably influenced the participation of some students. For the fourth field trip, the canoe trip, the third period class again had the lowest attendance rate, nearly 17% lower than the cohort did and more than 25% below rates for the other two classes. These data are represented as a change-over-time graph in Figure 5.

Figure 5. Percentage of students attending field trips by class period

5.1.1.2.3 Field trip attendance by ethnicity.

Clear differences between field trip attendance rates of African American students and attendance rates of all other ethnic groups can be seen in Table 14. For each field trip, attendance by African American students was substantially lower than that for the group with the next-lowest attendance. The one exception was the fourth field trip, for which the Asian American and African American attendance rates were nearly equal; however, with only three Asian American students, a single absence resulted in a considerably lower percentage. The attendance rate for African American students was 75% for the first field trip, dropped to 50% for the second trip, and was 67% for the final two trips. Conversely, attendance rates for White, Latino, Native American and Asian American students were consistently high (except as noted for

Asian American students)—above 70% in all instances, and more than 80% in most cases.

Table 14

Field Trip Attendance by Ethnicity

				Canoe Trip-
	Trip #1-Nov	Trip #2-Feb	Trip #3-Apr	May
Cohort ($n = 37$)	89	73	87	81
Asian American ($n = 3$)	100	67	100	67
African American ($n = 12$)	75	50	67	67
Latino ($n = 7$)	100	71	100	100
Native American ($n = 2$)	100	100	100	100
White ($n = 13$)	92	92	92	85

The differences in attendance rate between African American students and others, by ethnic group, were 17-25% for the first field trip, 21-50% for the second trip, 25-33% for the third trip, and 18-33% for the final canoe trip (excluding figures for Asian American students on the second and fourth trips). Changes in field trip attendance by ethnic group over the year are shown in Figure 6.

Figure 6. Percentage of students attending field trips by ethnicity.

To investigate possible relationships between ethnicity and class period, I analyzed field trip attendance rates for each ethnic group in the three class periods. Due to the low numbers in each subgroup, reporting the results was not useful; nonetheless, it was interesting to note that on the second field trip, none of the four African American students attended.

Taken together, these data reflect students' level of engagement and participation in the field-based component of the curriculum. The assumption of the co-teaching and research team was that contextualizing learning in the local environment would increase students' engagement in science. In general, this seemed to be true; however, exceptions emerged.

5.1.2 Evidence of Thinking

One of the goals of the science curriculum was to help students develop the ability to think critically and understand the process of science inquiry. The next series of analyses was designed to measure students' level of thinking and to notice any changes over time during the school year. Questions, hypotheses, and analyses from students' three work samples showed evidence of their thinking level. A Thinking Rubric, described in Chapter 4 and included in Appendix D, explains qualities of each level of thinking and was used to evaluate the work samples.

The frequency with which each level of thinking was observed, by trimester, for the whole cohort is shown in Table 15; the number of quotes analyzed each trimester was approximately the same. Overall, there was an upward shift, from low and medium-low responses at the beginning of the year to more medium-high and high-level responses by the end of the year. However, in the middle of the year there were more low and medium-low responses than in the first trimester. In other words, there was a modest increase over the course of the year, but a drop in the middle.

Table 15

Level of Thinking – Frequencies Observed in Cohort

Trimester	Frequencies					% of Medium-high and High
	Low	Medium-low	Medium-high	High	Total	
1 st	4	158	82	1	245	34
2 nd	7	180	58	1	246	24
3 rd	2	114	115	9	240	52

To make full sense of these data, and continuing to use the concept of change over time as well as subgroupings used elsewhere, I calculated the percentage of medium-high- and high-level quotes for each trimester and in subsequent breakdowns, by class period and ethnicity. Categorizing the data in this manner showed details of the increase in students' levels of thinking over the course of the school year.

5.1.2.1 By Class Period

The findings presented in Table 16 show in striking fashion that all three class periods exhibited the same trend—a slight decrease in the number of medium-high and high-level responses between the first and second trimesters, but a substantial increase in the third trimester.

Table 16

Percentage of Quotes Rated with Medium-High and High Level of Thinking, by Class Period.

	Trimester		
	1 st	2 nd	3 rd
Cohort	34	24	52
3 rd Period	30	28	53
4 th Period	35	24	54
5 th Period	37	21	48

Changes in the percentage of student responses that were rated medium-high and high are shown in Figure 7.

Figure 7. Change in percentage of quotes rated with medium-high and high level of thinking, by class period.

5.1.2.2 By Ethnicity

Frequency of levels of thinking in quotes from each trimester, broken down by ethnicity, are shown in Table 17. Unlike the levels of thinking within each class period, there were noticeable differences in pattern and degree of change among ethnic groups. Percentage of quotes rated medium-high and high for African American students dropped from 37% in the first trimester to 15% in the second trimester, then jumped to 44% in the third trimester, only moderately higher than the first trimester. Medium-high- and high-level responses from Latino students remained near 40% for all three trimesters, and those from Native American students rebounded but to a modest degree. The percentage of medium-high and high responses from the other two

ethnic groups, White and Asian American, matched and defined to a greater extent the trends of the cohort—a slight decrease between the first and second trimesters, with a substantial increase in third trimester.

Table 17

Percentage of Quotes Rated with Medium-High and High Level of Thinking, by Ethnicity.

	Trimester		
	1 st	2 nd	3 rd
Cohort	34	24	52
African American	37	15	44
Asian American	26	30	55
Latino	40	37	42
Native American	33	12	35
White	31	25	67

These data are shown as a change-over-time graph in Figure 8. Compared to the results by class period, the breakdown by ethnicity shows greater differences among subgroups.

Figure 8: Change in percentage of quotes rated with medium-high and high level of thinking, by ethnicity.

5.1.3 Evidence of Learning

5.1.3.1 Work Sample Performance – Class period

Median work sample scores, as well as maximum and minimum scores, are compared by class period in Table 18. It is relevant to note that in the cohort and in each subgroup, the median student scores were well below a four, which is the level required to meet the state standard.

Table 18

Comparison of Median Work Sample Scores by Class Period.

Class Period	Median			Minimum—Maximum			Number of completed assignments		
	WS-1 ^a	WS-2 ^b	WS-3 ^c	WS-1	WS-2	WS-3	WS-1	WS-2	WS-3
Cohort (<i>n</i> = 37)	2.75	2.82	2.66	1.00-4.38	1.25-4.62	1.50-4.25	24	30	24
3 rd (<i>n</i> = 15)	2.50	2.82	2.71	1.00-4.13	1.25-3.50	1.75-4.25	8	10	8
4 th (<i>n</i> = 12)	2.75	3.00	2.88	1.50-3.38	2.25-4.62	2.13-3.75	9	11	9
5 th (<i>n</i> = 10)	3.00	2.25	2.50	2.38-4.38	1.75-4.25	1.50-3.50	7	9	7

Note. Maximum score on each work sample = 6.

^aBrine Shrimp lab; ^bHeart Rate lab; ^cScience Inquiry Work Sample

Changes in median work sample score are shown in Figure 9. With the exception of the first work sample, median scores for the fifth period class were lower than those for the other two classes. The third and fourth period classes showed a trend similar to that of the cohort overall, i.e., a slight increase in score between the first and second work samples, followed by a slight decrease in the third work sample. The fifth period class showed a decrease in median score between the first and second work samples, with an increase between the second and third; however, the median score was lower in the third work sample than in the first.

Figure 9. Change in median work sample scores by class period.

5.1.3.2 Work Sample Performance by Ethnicity

A comparison of the median score for each work sample by ethnicity is shown in Table 19. As noted in the field trip analysis, it is important to recognize that the cohort included only three Asian American and two Native American students; therefore, interpretations should be drawn carefully. Additionally, since not all students completed the assignments, there were low numbers of work samples available for analysis. This was especially true for the brine shrimp lab, which only 5 of the 12 participating African American students completed; however, for the other two work samples, nine of the African American students completed the assignments, perhaps providing additional evidence of engagement.

Table 19

Comparison of Median Work Sample Scores by Ethnicity.

Ethnicity	Median			Minimum—Maximum			Number of completed assignments		
	WS-1 ^a	WS-2 ^b	WS-3 ^c	WS-1	WS-2	WS-3	WS-1	WS-2	WS-3
Cohort (<i>n</i> = 37)	2.75	2.82	2.66	1.00- 4.38	1.25- 4.62	1.50- 4.25	24	30	24
African American (<i>n</i> = 12)	2.50	2.38	2.50	1.50- 2.88	1.25- 4.25	1.75- 3.00	5	9	9
Asian American (<i>n</i> = 3)	3.25	2.88	3.13	1.88- 3.38	1.75- 3.38	3.13- 3.13	3	3	1
Latino (<i>n</i> = 7)	2.75	2.88	2.90	1.75- 4.13	2.25- 4.25	1.50- 4.25	5	7	6
Native American (<i>n</i> = 2)	2.69	2.57	3.50	1.00- 4.38	1.88- 3.25	3.50- 3.50	2	2	1
White (<i>n</i> = 13)	2.75	3.00	2.88	1.88- 3.38	2.38- 4.26	2.13- 3.75	9	13	7

Note. Maximum score on each work sample = 6.

^aBrine Shrimp lab; ^bHeart Rate lab; ^cScience Inquiry Work Sample

Median scores for the three work samples, by ethnic group, are shown as a change-over-time graph in Figure 10. Using this visual representation, a gap in performance can be observed between the African American and White students.

Figure 10. Change in median work sample scores by ethnicity.

5.1.4 Group Profiles

To make most use of the change-over-time concept from systems thinking, I organized the change-over-time graphs into group profiles for the three class periods, and for each ethnic group. A comparison of field trip attendance, level of thinking, and work sample scores is presented in Figure 11 (for class period) and Figure 12 (for ethnicity). This comparison of change-over-time graphs makes it easier to notice possible relationships among student engagement, thinking, and learning. Comparing the field trip results to the level of thinking, it appeared that as field trip participation decreased over the year, level of thinking decreased then substantially increased. Conversely, work sample scores decreased as level of thinking increased, and increased as level of thinking decreased. Viewed in a slightly different way, except in

the third period, students were engaged in field activities in high numbers (above 80% attendance), which could be related to the increase in level of thinking, but neither seemed to have an impact on student learning. A possible factor not captured in these profiles would be the impact of changes in the teacher's (that is, my own) practice and strategies over the course of the year. These interactions will be discussed more in later sections.

With the exception of the second field trip, attendance on field trips was generally high, possibly indicating that these field trips provided an engagement strategy to interest students in science. Although it is unclear whether there is a relationship between field trip attendance (engagement) and level of thinking, there was a substantial increase in students' levels of thinking over the school year. Nonetheless, as noted, there was no substantial improvement in work sample scores, which were generally low in all groups.

Figure 11. Group profile by class period.

Figure 12. Group profile by ethnicity.

5.2 Grounded Theory

The development of a grounded theory explaining the complex phenomena interacting in a typical urban middle-school science classroom was the culminating outcome of this mixed-methods study. In the first phase of grounded theory analysis, the main factors were identified from student-level data and the literature, and organized into three themes—science learning and understanding, adolescents, and cultural and linguistic aspects. These themes, including the categories and subcategories developed, can be found in Appendix F.

Through this first phase of analysis, many examples of cultural and linguistic tensions were observed and utilized to develop a model representing these tensions. In an earlier version of the tension model, factors related to teaching and learning were organized into four areas: students' cultures, adolescent development, principles of teaching and learning, and school culture and climate. Students' cultures included factors such as cultural and linguistic backgrounds and learning styles; adolescent development included students' self-image and middle school "angst." Ultimately, the two were merged. Principles of teaching and learning included factors discussed in Chapter 2 such as active construction of knowledge and building on prior understanding and experiences. School culture and climate included factors such as mainstream cultures including science, and the beliefs, practices and assumptions of individuals. A model representing the tension is shown in Figure 13. This model represents students and classroom experiences as central, while various factors are organized around the cultural tension.

Figure 13: Tension model

After this initial process of coding and identifying the main factors influencing tension in the classroom, I explored the core phenomena of student engagement, thinking, and learning in science by looking closely at the student-level data presented in the descriptive study results. The descriptive findings corroborated the concept of tension identified in the initial grounded theory analysis.

5.2.1 Phenomena Explained

Examples from student data will be provided in the several subsections of this section in order to highlight the phenomena in the tension model and the final grounded theory model.

5.2.1.1 Inquiry and Hands-on, Field-based Learning Opportunities

The main hypothesis of this co-teaching and research experience was that connecting learning to meaningful experiences in the local environment could provide culturally accessible points of engagement from which to build enhanced science learning and activities. Although there were dramatic exceptions to the supposition that inquiry-based science, contextualized in the local environment, is engaging and meaningful to students—such as those presented in the field trip attendance results—this hypothesis was generally supported by the empirical evidence analyzed in this study. There were numerous examples of students showing higher levels of engagement when they participated in hands-on activities that involved multiple approaches to learning. “Hands-on” activities were interpreted broadly to include activity and movement, as well as use of technology. In fact, on days when students used Vernier® equipment, they were consistently engaged and on task (Field Notes; Classroom Observations, 5/2/07).

Students provided evidence supporting the notion that young adolescent learners need opportunities for interactive, hands-on learning activities. The following conversation is from the second focus group, consisting of all boys:

Interviewer: “One last question. How do you guys best learn science?”

Mark: "Instead of staying in the classroom all the time, going on field trips. Go there and see it for yourself. It makes you want to learn it because it is funner, instead of staying in the classroom all the time, you get to go see what you are learning about."

Nate: "It's more exciting."

Oswald: "I think the experiment because you can see what you're learning about. How you see with the microscope. Textures and stuff."

Halian: "Hands-on is the best."

Mark: "When you're right there doing it."

Halian: "Instead of sitting in the classroom reading books."

Mark: "Instead of reading about people doing it. You are there. Actually doing it."

(Focus group 2; June, 2007)

The students expressed self-awareness of their learning preferences during the focus group conversations. These comments could indicate varying levels of metacognitive skill, suggested by the comments in this last passage related to hands-on activities: "... you're right there doing it ..."; "... instead of reading about people doing it. ... Actually doing it." The comments could also show that hands-on work involves a heightened use of metacognitive skill.

Another example was expressed in the third focus group, consisting of all girls:

Interviewer: "How do you feel you best learn science?"

Ramona: "Hands-on learning. Kinesthetic learn[ing]. Hands on, because it is active"....

Ida: "... I do much better when we are outside doing something I love. Like science or other things, like canoeing or observing wildlife, catching insects in the water and stuff. I agree with Ramona, the more active, the more better I get stuff. I get to learn a lot about it"

(Focus group 3; June, 2007)

Not surprisingly, some specific activities were mentioned multiple times in the focus groups. An example was a River School lesson on the water cycle that not only emphasized multiple modes of learning but also seemed to have helped students gain an understanding of the central concept.

In this lesson, students learned about the water cycle by playing a game that modeled the way a drop of water might move through the cycle. The following interchange touched upon several interesting phenomena, including ways that students process and verbalize their thinking, and ways that conversation can help students socially construct understanding:

Nancy: "... Like in the beginning of the year in November, we had a dice and we would roll it. There was water and there was earth and we did the bead game."

Ramona: "Each bead represented different things like earth, water, animals, plants, clouds ... what else? You had a black ... [questioning look] ... what is it called?"

Interviewer/me: "Pipe cleaner?"

Ramona: "Yeah, pipe cleaner. And you would put a bead on a string and it represents what you did and the cycle of things. How it ended up ... And then there was the salmon game which we didn't play. We had a board and you started out with 1000 eggs. It is everyday stuff that a salmon would go through to get to its spawning area. And if there is too much pollution in the water you lose too many eggs. Then you see how many eggs you have left over when you get to the spawning spot. It is very interesting."

(Focus group 3; June, 2007)

Ramona's monologue provided evidence of her interest and engagement in science activities, and how much she retained, learned, and understood.

Students in the first focus group also discussed the water cycle lesson. This next conversation shows how students recalled the activity and the concepts learned in this engaging, hands-on lesson:

Evan: "I liked the activity when Ms. F came in and we used the beads and we made the bead things and we had to walk around and see what water molecules do over the course of their life. You usually had to draw the clouds."

Estelle and Sydney: "Oh yeah!"

Renée: “Oh and I remember that too. Each one – a river was blue and the clouds were white. Like where the water molecules would go. I remember that, too.”

(Focus Group #1; June, 2007)

These students not only expressed recall of the water cycle lesson, but also seemed to build a deeper understanding of the concept through their discourse. The lesson utilized elements that supported multiple learning styles, including kinesthetic, active, movement-oriented activities; a literary/story-telling component; and tools for understanding the mathematical concepts of probability and time.

Despite the overwhelming agreement among students that “hands-on is best,” (Halian, Focus Group 2), they also expressed an understanding that in some cases, other approaches to learning were more appropriate and helpful. Several students mentioned PowerPoint presentations. Although most thought they were secondary to hands-on learning, students often found value in a good PowerPoint presentation. Nancy probably expressed this idea best when she said, “I think the PowerPoints [helped us learn] because sometimes it might be hard to say it or explain it for a teacher, but with a PowerPoint it helps to make bullet points” (Focus Group #3; June, 2007).

Nancy’s comment is also interesting when considering differences between teachers and students in language and expression of ideas. Perhaps PowerPoint presentations can help students see the main concepts and bridge the gap between their everyday language and the language of science. Similarly, with large numbers of English Language Learners, PowerPoint could perhaps provide a method of supporting language acquisition.

This next passage provides further evidence that one size does not fit all, and points to the need for differentiated instruction to reach all learners.

Interviewer: “How do you best learn science?”

Sydney: “... By listening to the teacher and PowerPoints and doing assignments and activities.”

Estelle: “How I most learn is writing down notes.”

Renee’: “... Being able to look your data over ...”

(Focus Group #1; June, 2007)

Renee’, Sydney, and Estelle expressed learning preferences for approaches other than hands-on activities; i.e., for approaches often considered to be mainstream approaches in teaching (e.g. lecturing with a PowerPoint). Each of these individual, African American girls brought cultural tools to school that helped them navigate the tensions experienced in mainstream education. For example, Renee’ came from of a middle-class experience, which was different from most of her peers. Sydney had moved to Portland from Las Vegas; therefore, her earlier years of childhood and youth were shaped by a very different community context. In Estelle’s case, her background was more similar to the other African American girls in the study; however, Estelle seemed to possess unique personal traits that set her apart. There were several instances observed over the year when Estelle demonstrated higher levels of personal confidence and insightfulness than usually observed in young adolescents of any background. Although at first glance, none of these girls would have appeared part of the mainstream culture—i.e., White, middle class culture—each possessed some experience or personal quality that allowed them to find success with traditionally

more mainstream approaches to teaching and learning such as lecturing, note-taking, and PowerPoint presentations.

5.2.1.2 Students' Knowledge, Skills, and Attitudes

Intrinsic motivation was a factor in students' engagement, thinking, and learning in science; however, identifying and measuring motivation is complex. Nonetheless, students demonstrated high levels of motivation and commitment to learning at various times throughout the year. Sydney provided evidence of her motivation and dedication to learning when she came to discuss how to make sense of her Vernier® graphs outside normal class time. After considerable back-and-forth explanations and clarifying questions, she got it, exciting both her and her teacher (Sydney's work file; Reflection, 05/26/07).

To perform learning tasks that required higher-order thinking and active processing, students needed to be equipped with a certain skill set. Unfortunately, there were many examples demonstrating how unprepared students were. Organizational skills and writing abilities were two main issues that arose. Students in the second focus group discussed some of these challenges in the following passage:

Nate: "The confusing thing was when we was writing the paper because I lost things, I didn't know where to start from, and I kinda got off track."

[Oswald nods in agreement]

Halian: "The most thing I hated was those papers because I would get to a point where I didn't know what was right because I didn't have all my stuff and the second thing that was hard was the science fair because I couldn't write down all the stuff because we didn't collect enough data."

Mark: "Yeah ... yeah ... um, that's what I didn't like the most either."

Interviewer: "The science fair?"

Mark: "No, the writing. I hate writing in the whole school."

Nicolas: “Me, too, the writing. I wouldn’t know what words to start with or what words to end with.”

(Focus Group #2; June, 2007)

In this interchange, the students discussed their struggles with writing, finding it confusing, not knowing how to start or end. They expressed organizational challenges as well. Perhaps if project work were integrated across the disciplines, students would have more support and gain a better understanding of the writing process. Generally, language arts teachers are more skilled at helping students learn to write. Similarly, since teachers in other disciplines are often uncomfortable with science, they may not routinely teach scientific or expository writing. By working as an interdisciplinary team, the overall teaching and learning process could be improved. Students might still be confused, but students would likely gain more writing skills, and have more time to participate in science learning activities.

5.2.1.3 Adolescent Development and Middle School Dynamics

Peer relationships and self-image contributed to the ways students navigated their learning. Numerous examples of peer dynamics, middle school “angst,” and positive or negative self-images were expressed in the student files, focus groups, and field notes and reflections. As in most middle school environments, relationships were of utmost importance to students. Nearly every day there was some level of drama or crisis, and these incidents greatly impacted the overall classroom environment. Although these incidents were harder to tease out from the data, examples of students’ self-images showed up in many forms.

Through data analysis, I came upon many examples of students expressing positive or negative self-images. In the fourth focus group, Eduardo provided two glimpses of a student gaining confidence, leading to improved self-image over time.

First, when he was talking about what he learned, he said:

... About dissecting the fish. 'Cause I really didn't have courage to dissect it. But then when I saw Donald and someone else, I got more courage in me. So I started helping them out, and then they were tired, so I did the rest. I found the heart and I even found the brain (Focus Group #4; June, 2007)

In this quote, Eduardo articulated the way his engagement was triggered—apparently by seeing peers start the dissection—and then he “got more courage.” He not only participated in the dissection, but also found body parts that can be very difficult to find. He learned skills of life scientists in practice, and performed them at a high-level of proficiency. Eduardo also responded to a question asking whether he felt his perspectives about the local environment had changed:

The area where I live there is a lot of trash on the streets and on the sidewalks, and me, by myself, I go outside and put some gloves on and I get a big large bag, and I pick up the garbage. People in my area say, “he is a really wonderful kid” and everything. And people start saying things like I am a good kid (Focus Group #4; June, 2007)

In this response, Eduardo seemed to address his self-esteem and image of himself. He implied in his response that his self-image has improved because he picked up litter. Apparently people were impressed by his efforts, and this reality (or possibly perception) helped Eduardo gain a sense of pride and self-worth.

In the second focus group, Ingrid and Nancy both had interesting responses to the same question asking whether they felt their perspectives about the local environment had changed. Ingrid said:

Before I have gone into sixth grade science, I haven't liked nature as much and I haven't paid attention to it. But then when I got into sixth grade I felt that it was important and that I should pay attention to it. I should help it and helping my brother along with that. So sixth grade has changed my perspective of looking at nature and how important it is It was Outdoor School and Project Citizen that got me into how important it is (Focus Group #3; June, 2007)

Ingrid's response was interesting in the way it provided insight into her self-image, but also as it related to an important aspect of adolescent development. In this quote, Ingrid expressed the way her perspective had shifted from a self-centered orientation that is developmentally typical of younger children, to a more global perspective. Furthermore, she attributed this developing perspective to the projects she experienced in science and social studies:

Nancy expressed a similar idea:

... It changed me because before Outdoor School, I knew it was there, I go camping every summer probably three times ... but then after outdoor school when we did the pH testing, I realized how much oil and things could affect the rivers and the environment around us (Focus Group #3; June, 2007)

Nancy seems to have developed more of a global perspective, too, and she expressed an understanding of connections in a watershed. Furthermore, Nancy seemed to gain an appreciation for something she may have taken for granted before (i.e. camping each summer).

Students were very interested and excited to share their plans and visions for their futures, providing insight into their aspirations and self-images. Focus group conversations revealed a lot about students' plans for high school and beyond, such as this conversation in the fourth focus group:

- Eduardo: "... Well, I want to go to a four year college and to try to be a lawyer, and charge a lot of money per hour."
- Rudy: "I think I want to either be a video game maker, or open a restaurant and do that kind of thing."
- Alicia: "OK, um, my idea is that I want to go to a four year college, and then when I graduate I want to be a video game maker. That is if I can't do what I wanted to do. That is one of my backup plans. What I kind of want to do is have my own restaurant, or be a restaurant manager. Right now my cousin is going to the western culinary institute and he is going to be a restaurant manager, and he found a job and about a week later he was promoted to assistant manager over 300 other employees. When his manager retires he is first runner up for manager"
- Nell: "... OK, well of course I want to do college. I want to try to be a doctor even though it is going to be a long time in college. But I like to cure people. And help people so that is why I would like to be a doctor."
- Eduardo: "... My parents always say to have a backup plan in case you don't get what you want. Like I want to be a lawyer, but I always thought I need to make a backup plan in case of emergency. My plan A is lawyer. Plan B is helping the environment in Portland. For the community."
- Lisa: "... Well, I definitely want to go to college and I want to be, like, I don't know how to put it, but not necessarily a professional dancer. But someone who does ballet, theater. I want to be in a dancing company. Plan B is I was going to open a restaurant. I even have a Plan C. I want to help the environment."

(Focus Group #4; June, 2007)

Students were animated during their responses to this question. They seemed to have big ideas and plans for themselves—seemingly a good sign for their self-images.

Related to self-image are students' scientific identities. It sometimes seemed that students did not realize the importance of science in their everyday lives as pointed out by Ida's response to the question about future plans: "... This has nothing to do with science but I want to be a pediatrician. That way I could help people," (Focus Group #3; June, 2007). This comment yielded insights into Ida's goals, but also highlighted the way students often do not realize the significance of science learning in their lives.

Though it may seem unrelated at first glance, the importance that food played in student dynamics came up on many occasions. Students were provided healthful food and beverages during each focus group interview. In some cases, students were more focused on the food than the interview questions, as witnesses in the second focus group:

Nicolas: "Can I get some more chips?"

Interviewer: "Let's get through this first ... OK, so we are going to move on."

Mark: "Are we going to get the Twix?"

(Focus Group #2; June, 2007)

Food was keeping these students going, and they wanted to make sure they got some of everything. Similarly, when asked about their least favorite activities, the boys had food-stimulated memories related to the first field trip:

Mark: "The hot cocoa was nasty. It was watered down."

Nate: "We didn't do that."

Mark: "That was nasty, it was watered down."

Oswald: "There was too much water."

Nicolas: "It was hot water."

Mark: "It was like a teeny bit of chocolate and all water."

Nicolas: "There was too much water."

Halian: "It was thick and weird."

Interviewer: "Anything else besides the hot chocolate?"

(Focus Group #3; June, 2007)

5.2.1.4 Students' Past Experiences, Existing Knowledge, and Cultural Assets

Students' work and responses to journal prompts provided numerous examples of opportunities taken to draw on their past experiences or cultural backgrounds; however, these were rarely utilized to the full extent. In the flowing piece of student work, Nancy provided an example of the way students negotiated meaning and made sense of new and existing knowledge. In this work item, she drew on past learning,

knowledge, and experiences when she stated her hypothesis about carbon dioxide levels in the gecko's cage compared to the rest of the science classroom:

My hypothesis is, I think that Summer would breathe out the same amount of CO₂ from the tank compared to the room. The reason I think this is because I was near the tank during the experiment. So CO₂ evaporates to the plants. We had plants in the room so the CO₂ would start to move towards the plants, as if plants breathe in CO₂ and out Oxygen. (Nancy's student file; 5/24/07).

5.2.1.5 Social Construction of Knowledge and Understanding—Sense-making

Although students varied widely as to whether they liked group work or not, they consistently constructed knowledge and understanding socially. Several of the following exchanges not only demonstrated the social construction of knowledge and understanding, but also began to show how the various factors related. This exchange came from the first focus group when the students were asked what learning they felt would stay with them beyond the current year:

Renée: "... The most important thing I'll remember is what the inside of a fish looked like and what brine shrimp are."

Estelle: "... What I remember is our anchor paper." [Heart rate]

Sydney: "... Science inquiry project ... what was that inquiry project that we did?"

Renée: "Oh, science fair."

Sydney: "I think I'll also remember the science fair because it was a lot of hard work and I remember the night before and I remember all the days I skipped practice for drama and how I stayed after school a lot."

(Focus Group #1; June, 2007)

Several important points appeared in this exchange. First, through conversation, the students socially recollected activities they remembered from the school year.

Although these recollections implied learning, they were an even stronger indication of students' interest and engagement. In Sydney's last comment, she not only

expressed interest and engagement, but also a strong commitment to completing her project—even sacrificing her drama practice.

In the fourth focus group, when asked what their favorite thing was in science for the year, the students responded with an unequivocal, unanimous response: the canoe trip. This was the case for most of the focus group participants. When asked what their second favorite activity was, they responded:

Alicia: “The water tests when we would get the nets and put them in the bucket. In most of our buckets we had little small dead fish. We found lots of small macroinvertebrates.”

Isabelle: “My other favorite was when we tested the water temperature to see what animals lived in it.”

Nell: “I’ll go with Alicia, my favorite and what we mostly see in our water was the mayflies. I liked that.”

Eduardo: “I’m the same as Alicia.”

Lisa: “... I liked the pH tests.”

Alicia: “I have something to add, one of my favorites was the water temperature one. When we break the cup and we test the different colors.”

Isabelle: “The pH, that’s the same thing.”

Alicia: “No, I don’t think so.”

Interviewer: “Does anyone remember what that was? The ones with the glass tubes that you broke?”

Lisa: “Dissolved oxygen?”

Interviewer: “Very nice. Yes.”

(Focus Group #4; June, 2007)

This discussion demonstrated the way that students built off each other’s answers, in this case recalling the water chemistry field trip. Furthermore, it seemed that the students had begun to build an understanding of some of the main concepts about watersheds. It should be noted that the water chemistry field trip was in November, and the macroinvertebrate field trip took place in April. One of the learning goals for River School was for students to understand the relationship between

macroinvertebrates and water quality and to know that macroinvertebrates could be used as an indicator for water quality. Although the depth of understanding was not clear from this conversation, it appeared the students made some of these connections.

Examples of the ways students socially constructed knowledge and understanding were also found in the student work files. For example, students were provided with a graphic organizer known as “KWL” (K = What you know; W = What you want to learn; L = What you learned), to help them gather and organize background information for the heart rate anchor assignment. These sheets were part of the analysis of student work files, specifically the questions students posed in the W section of the worksheet. This analysis revealed several instances in which students had the same responses, including Nate and Halian (i.e., Nate’s and Halian’s student work files). In this example, students were generating ideas collaboratively and socially making sense of information they gathered. This finding has implications for addressing the tension between the cultures of mainstream school and science, and the socio-cultural backgrounds of students.

5.2.1.6 Resistance and Reluctance

Both the field trip data and students’ work provided instances when students seemed to avoid participation. Resistance and reluctance were terms I used to describe the nature of students’ disinterest in certain activities—i.e., the field-based activities in this context. Reluctance referred to a situational unwillingness to participate, and resulted from social dynamics among students, lack of preparation for the conditions in the field (e.g. inappropriate footwear or outerwear), or even a bad mood for the day.

Generally, reluctance was short-term and easier to overcome. Resistance, on the other hand, referred to a deeper unwillingness to participate that persisted over time. Overcoming resistance was difficult at best, and more than likely, the underlying causes may have been rooted in sociocultural practices and beliefs, and/or historical patterns of oppression and resistance.

For example, on the first field trip, students experienced very cold temperatures, and many were unprepared for the weather. After that experience, many students were not enthusiastic about going on the next field trip in February; this was an example of *reluctance* to participate in field experiences. Other students, however, were generally *resistant* throughout the year (ingrained vs. situational). These students often refused to take home permission slips, or would choose in-school suspension over the field trips. Despite evidence that inquiry and field-based approaches were engaging, there was also evidence of resistance and reluctance to participate. Whether this was due to social interactions, discomfort with the unknown, or a combination of factors, resistance and reluctance to field activities were observed, and to a large degree, were unexpected.

The descriptive portion of this study highlighted resistance and reluctance as they related to field trip attendance. Other examples in different situations and contexts were also observed, including this statement from Ingrid about the fish dissection:

The most confusing part was the fish because I didn't know which was what and she showed us two days before and I refused to watch because [the] smell was making me sick. But the day that it came around, I did dissect the fish. My

partner just watched. So she helped tell me which was which. (Focus Group #3; June, 2007)

This example showed how a student overcame initial reluctance, and eventually participated with a high-level of engagement. It is also important because as a White female, Ingrid showed that issues such as reluctance were not limited to any particular ethnicity or gender.

5.2.1.7 Communication Styles, Linguistic Differences, and Artistic Expression

In nearly every student file, there were examples of students' expression and communication styles. Most of these were not in alignment with traditional, mainstream science. There were language differences among English Language Learners (ELLs), linguistic styles that may have underrepresented what students understood, and numerous examples of preferences towards artistic and visual expressions of learning.

Sydney provided an example of the way students often seemed to grasp a concept—sometimes quite complex in nature—but struggled to explain it in words. In her answer to the Outdoor School workbook question about why some rivers are faster or slower than others are, she wrote:

Because there is no rocks and stuff holding it back and then when it gets closer to the middle it steps down from rocks and stuff holding it back. (Sydney's work file; 10/06)

In her answer, Sydney seemed to express a visual, mental representation of rivers, but her words were hard to follow.

In another example from the first focus group, Eduardo, a native Spanish speaker, expressed the way that language barriers impacted his experience. He said:

I do not like tests and quizzes, but in science when Ms. Irvine was doing PowerPoints, she was going too fast and sometimes I missed really important information and that is why my tests and quizzes got bad grades. (Focus Group #4; June, 2007)

As an English Language Learner, taking notes on new scientific information was difficult for Eduardo, pointing to the need for extra language supports and scaffolding of complex ideas.

5.2.1.8 Importance of School Time

As Valerie Evans described in the summer institute on cultural proficiency, many students in this study would have been described as “school dependent,” meaning time in school was more critical than for students who may have had more learning activities in their everyday lives. Nicolas made a comment related to the science fair projects that spoke to this issue:

The science fair because we had to do it out of school instead of in the school. If we did it in the school, it was too short. We should have had more time. It was hard for me to choose what I wanted to do. (Focus Group #2; June, 2007)

The mainstream assumption that students will be supported at home when they do projects such as a science fair does not necessarily hold for school dependent children. Therefore, it is important to have structures in place during the school day—i.e., enough time and support—to allow students to get through the learning processes.

5.2.1.9 Curriculum that Supports Learning

Some students expressed challenges and sources of confusion. In the fourth focus group, Rudy pointed out that students often have had little or no experience with inquiry-based learning:

... I think just about everything was confusing to me at the beginning but towards the end of the year I started to learn more about it all so it is easier now I didn't learn much in science last year or anything that we learned this year. (Focus Group #4; June, 2007)

In this quote, Rudy explained how at the beginning of the year, everything was new and confusing, but as the year progressed, he learned more and seemed to gain confidence in science. Rudy's comment raises an important point about the ways that educators support science learning. Since students often come with limited prior experience with science and inquiry, students need supports and "instructional scaffolding" to help them build their understanding. By the time students get to middle school, if they have never experienced inquiry-based learning, teaching and learning to the levels expected by the Standards (NSES, 2000) will be more challenging than among students who have experienced science and inquiry throughout their elementary education. This point highlights the importance of well-planned and well-implemented science instruction.

The following conversation emphasized the importance of providing students with multiple learning opportunities, particularly for key concepts in the curriculum. In the fourth focus group, the students had been talking a lot about Outdoor School, so they were asked if they learned more about those topics in River School or in the science class in general:

Isabelle: "Well, with the pH we learned it at Outdoor School, and then we learned it on the field trip, and then you brought it up a little bit, and we remembered it once we did it more than once."

Alicia: "And then I think all three of them, River School, science class, and Outdoor School connected to help me learn science. It was Outdoor School [that] taught you a fun way to learn science. You are getting into more detail in class. And River School, we got to learn about fishes

and temperatures; that goes with the science class and Outdoor School because we learned about those things too. They all connect pretty much for me.”

Nell: “What I think that connects, if you learn something about something at Outdoor School, they could give you information, but not enough. If you learn from science, they can give you more information. If you add them together, you know a lot more information.”

(Focus Group #4; June, 2007)

These responses aligned with what we know about learning and the importance of reinforcing concepts—the idea of a spiraling curriculum. The fact that these girls could identify places where their learning activities connected over the course of the year implied some level of learning. Nonetheless, not clear from their responses was the depth to which they learned the concepts.

When students encountered the same concepts at different times throughout the year, they seemed to gain deeper understandings. For example, when talking about the various field trips and environmental science experiences, Isabelle said:

River School helped but so did Outdoor School because they showed us ... one thing they taught us for a whole day was always stay on the path because if not, you could be killing a plant and even if it is not there yet, it will be there in a few years. All of it wraps around each other. If you ruin one thing it could affect another and ruin it. (Focus Group #4; June, 2007)

Isabelle not only reinforced the notion of a spiraling curriculum, but she also expressed understanding of a complex idea—the cyclical patterns of nature and the consequences of our actions. Although this understanding may not have been caused by Isabelle’s experiences in sixth grade science, it seems fair to assume that her experiences in science helped shape this understanding.

5.2.1.10 Teacher Knowledge, Skills and Attitudes

The importance of excellence in teaching for student learning and closing achievement gaps has been well established (e.g., Penske & Haycock, 2006). So has the fact that it generally takes 2-4 years before a teacher reaches her teaching potential (Laurence, 2007; Penske & Haycock). Based on my review of the sixth grade curriculum and lesson plans, I developed many enhanced teaching strategies over the year. Although students' work sample scores did not noticeably improve over the year, the striking increases in levels of thinking may be related to my efforts as a teacher.

Despite any improvements I made over the year, there were also examples of ways that I or my co-teachers may have inadvertently made errors in instruction. Although teachers are only human, it can be problematic when teaching errors lead to misconceptions among students. An example concerned watersheds; an activity planned early in the year was intended to help students draw on their existing understandings by using a tool shed as an analogy for a watershed. The teachers asked students to think of what they knew about tool sheds and to write what they thought a watershed was in their journals. Unfortunately, according to the River School educator, many students think watersheds are the big water storage tanks visible in several areas of north and northeast Portland. For students that already had this conception, comparing a watershed to a tool shed reinforced the notion.

Alice provided a typical response to this journal prompt before the lesson: "I think it is a place where people put rain barrels full with water." After the lesson, students revisited their answers and wrote what they understood. Alice wrote, "The

land where water drains in and is stored,” (Alice’s file, 9/29/06). The question that remained however was which conception would stick with students for the longer term. Based on a modest understanding of conceptual change theory, students’ conceptions and misconceptions are often well established in their cognitive structures. If a lesson does not deeply address misconceptions, it is likely that they will persist over time. This example shows how despite good intentions, sometimes teachers inadvertently reinforce misconceptions or fuel misunderstandings.

Technology can present other challenges when utilized as a teaching tool in science. Through the magnet grant, the school had purchased a significant amount of Vernier® equipment as well as SmartBoards®, document cameras, and projectors for every classroom. The Vernier® equipment was particularly relevant for teaching and learning in science; however, the teaching team was learning how to use the equipment and to understand the data. As a result, the teacher was often only a step or two ahead of the students.

In one example, the teacher was helping Nate’s group make sense of their temperature measurements for their final science inquiry work sample, investigating whether some liquids heated up more quickly than others did. The teacher told Nate and his group to pay attention to a section of graph that had a perfectly straight line, thinking this was the section where they had accurately measured heating or cooling; however, after reflecting on this interaction, the teacher realized this was wrong. In actuality, it was the highly varied section on the graphs that represented actual temperature measurements (Field notes; May, 2007).

5.2.2 Emergence of the Grounded Theory Model

Similar to the process of theory generation described by Creswell (2008), the concepts that emerged from this study and from the literature were synthesized into the theoretical model shown in Figure 14. This model provides a simplified explanation of a number of complex phenomena and the way in which they interrelate. To arrive at this model, I synthesized the themes identified from grounded theory analysis with findings from the descriptive study and concepts in the research literature. In this process, three “intervening conditions” emerged—student factors, teachers and teaching factors, and school culture and climate. Student engagement, thinking, and learning in science, together were considered the “core phenomena” (modified from Creswell, 2008 pp. 437, 445, & 446).

Figure 14. Theoretical model of student engagement, thinking, and learning.

A grounded theory explains the assumptions and propositions that the model explicates (Creswell, 2008). For this grounded theory model, which shows the way an array of phenomena must align for learning to occur, the following propositions explain the relationships among assumptions and propositions:

Table 20

Propositions Explaining Grounded Theory

-
- If the desired outcome is to have a scientifically literate and critically thinking population, which has been argued to be critical for achieving ecological sustainability, then students must be engaged in science so they can develop deeper levels of thinking and learn with understanding—the core phenomena
 - Currently, tensions exist between the mainstream culture of schools and the socio-cultural backgrounds of students, and these tensions prevent varying degrees of student engagement, thinking, and learning in science. This tension must be mitigated for engagement, thinking, and learning to occur.
 - For student engagement, thinking, and learning to occur (the core phenomena), there must be alignment/congruence between the three main intervening conditions - student factors, teaching practices, and the school culture and climate.
 - Each of these intervening conditions is comprised of numerous contextual aspects, compounding the complexity of the overall system.
-

As stated in the propositions, for the core phenomena to take place—for students to become engaged, to think, and to learn—there must be congruence and alignment of the “intervening conditions” —student factors, teaching practices, and

school culture and climate. When alignment and congruence occur, the tensions between the mainstream culture of school and the socio-cultural backgrounds of students are mitigated. This alignment—harmony among these factors—represents the “causal condition” that allows student engagement, thinking, and learning to occur.

Each intervening condition is influenced by contextual or situational factors. For example, intervening conditions relating to students include their cultural experiences and linguistic patterns; ethnicity, gender, and socio-economic factors; personal characteristics such as self-image, identity, and level of motivation; knowledge, skills, and attitudes; relationships; and family situations. Teachers and teaching practices are influenced by teacher education (pre-service preparation and ongoing professional development); pedagogy; curriculum and lessons; professional learning community; administrative support; knowledge, skills, and attitudes; relationships; and identity. Finally, school culture and climate are influenced by the interpersonal relationships in the school; by local, state, and national policies; the values, beliefs and assumptions of individuals; leadership; funding and budgetary issues; and other system-level influences. This grounded theory model provides a simplified representation of the complexities of teaching and learning, and the educational system overall.

5.2.3 Model in Use

To provide an example of the ways the grounded theory model presented in this dissertation could be used to build a deeper understanding of specific situations and personal interactions, I will highlight stories of two students. I will present

Ramona's story first. Ramona, probably more than any other student in this study, identified herself as a scientist. She was convinced that she would someday be a famous herpetologist, and this passion had been fueled by a life-long love of reptiles. Despite Ramona's strong passion for science, she had numerous circumstances working against her—I will call them “risk factors,” as they risked her future in science.

The other student I will highlight is Yvonne. In some ways she is an unlikely candidate since she did not participate in any of the focus groups. In addition, since she was in the fourth period class most of the year, I did not interact with her as much as I did with students in the third period class. Nonetheless, her story exemplifies some of the phenomena related to teachers' attitudes and the complex nature of the classroom environment.

5.2.3.1 Ramona

Ramona was a unique case from the first day I met her. She was a strong personality, and as she made clear early in the school year, she usually did not get along with female teachers. Ramona's life experiences provided her with risk factors she had to deal with on a daily basis, but her personal drive seemed to compensate for many of them. Risk factors were that Ramona lived in poverty, had experienced abuse, was on medication for ADHD, and struggled with anger management. Fortunately for me, science was one of the few school subjects that she loved. Although she rarely completed an assignment, as shown in her rate of work completion, she was highly engaged during each field trip and any time we did hands-on or lab-based activities in

class. Although she did not produce many examples in her work file, based on the quotes that were scored, Ramona's level of thinking approached the moderate-high level. This was confirmed by my own interactions with Ramona. In fact, my experiences with Ramona convinced me that she was a deep thinker and had understandings about the natural world that other students did not share.

These understandings were undoubtedly shaped by her early childhood experiences living in a rural area outside of Portland. She reflected fondly on memories from that environment, and often seemed to blame her struggles on her move to the city. Fortunately, her experiences in science helped her change her perceptions about living in Portland. In the third focus group, she addressed this directly when she said:

I used to live in the country so everything was like really good and then I went to Southeast Portland and then, now I live in North Portland and I just think that the city sucks. No trees or pretty rivers, nothing to do. No canoeing actually. Going to River School changed that. I didn't know that there were some pretty little ponds with eagles that killed fish or that we could go canoeing. That was really awesome. I think it kinda changed my whole perspective on the cities, in North Portland especially. (Focus Group #3; June, 2007)

Ramona's childhood experiences must also have contributed to her science-oriented identity and self-image. Few students considered themselves a part of science like Ramona did:

Ramona: "... [W]hen I want to grow up I want to be a herpetologist. That is the study of reptiles. And a zoologist. Look for Ramona when I grow up as far as zoology.

Researcher 2: "When did you decide you wanted to do that?"

Ramona: "When I was little. I put snakes and spiders in my pocket. I would capture them. I have been obsessed with animals and especially reptiles my whole life."

(Focus Group #3; June, 2007)

Despite her scientific identity, however, Ramona's self-esteem in general often seemed low. For example, during the focus group, she discussed her frustration with an activity in which students used raffia to make small ropes, similar to ropes made by indigenous people. Ramona said:

I had a little trouble when we were braiding the little things; I am ADHD. I couldn't do it for a while. It was probably because I am blonde sometimes. ADHD and blonde really don't go [laughter from the group]. (Focus Group #3; June, 2007)

Although Ramona got laughter from the group and said these things with humor, it was obvious, especially from other examples through the year, that Ramona believed these labels to a certain extent.

Ramona's early childhood experiences in nature were atypical when compared to those of most Carver students. Whereas many students were uncomfortable with the outdoors, Ramona was passionate about nature and life in the wild. She made several comments during the focus group that highlighted this reality, including this one:

And that time that we went, we saw an eagle which came out of the edge of the water and it came with a fish in its talons. We were all pretty fantasized by that. We thought it was awesome. I guess Whitaker Ponds is where we went. We had a really good environment. Like the water was really clean. We could also tell that by collecting the macroinvertebrates. So they can tell if the water is tolerant or intolerant. Then the eagle, I don't know if it is picky or not, but the fish, that was really awesome. (Focus Group #3; June, 2007)

This example not only highlights Ramona's enthusiasm about nature, but also shows some of the concepts she had learned.

Ramona was one of the most vocal advocates for hands-on learning opportunities, but she recognized and expressed the way that other teaching methods helped her learn, too:

As boring as PowerPoints are, [laughter from all], if you paid attention. I really like hands-on learning. But some things that were on the PowerPoint, like the different cells, I had no idea that there were cells and cells in a little square centimeter on your skin. I think that is really going to stick with me. There is like a whole human body living there, it is really amazing. If it wasn't for that boring PowerPoint, then I wouldn't have learned that. (Focus Group #3; June, 2007)

A bit later in the focus group, Ramona reinforced the idea of using multiple teaching methods based on some misunderstandings she expressed. Although she loved the activity, she did not understand what it was supposed to convey:

Ramona: "We did something with eggs. Chicken eggs?"

Interviewer: "The brine shrimp eggs?"

Ramona: "Unfertilized eggs, and we did an experiment on what chemicals or liquids would do to them, I didn't understand it and it confused me. I didn't understand why it did that. I can understand like the dye in Kool-Aid or something like how it would make the egg pink, but how it would affect it in other ways. I was confused on that, but I loved it."

(Focus Group #3; June, 2007)

It is probably safe to assume that if Ramona did not realize that the egg was a model for a cell, then other students missed that connection as well. To help students make connections between fun, hands-on activities and the underlying concepts they represent, high quality teaching is critical. Data from this year of co-teaching show many examples of success, but many challenges as well. I was probably better prepared than most first year teachers, yet for my own part, I was overwhelmed by the realities of the classroom.

I have highlighted Ramona because her story pertains to so many of the student-related factors presented in the grounded theory model above. She has personality and temperament traits that impacted her school experience. She drew on rich experiences, though mostly they were different experiences from her peers'. She

struggled with learning challenges in the mainstream culture of school. Nonetheless, Ramona was all about science. Getting to know Ramona through the school year made me wonder where her future will lead her, and whether her personal drive and passion will be enough to carry her through. She had circumstances in her life, “risk factors,” that will likely make accomplishing her goals more challenging, but perhaps her internal motivation, combined with caring adults, will help her achieve success.

5.2.3.2 Yvonne

Yvonne was another interesting example, in this case highlighting group dynamics including issues of power, control, and authority. Yvonne spent most of the year in the fourth period class, and she was the student with whom Ms. Irvine had the most ongoing struggles. Personally, I think Yvonne was rather shy and felt awkward at times, sometimes resulting in inappropriate laughter. Ms. Irvine took these outbursts as disrespectful and rude, and the tension between them grew over the course of the year. When Yvonne was moved into the third period class near the end of the year, I had a very different experience. I found her to be respectful, and despite her own adolescent angst, to her peers she was popular and seemed to be a leader. When she moved into third period, it seemed to me that her presence dramatically changed the dynamics of the class for the better. Whether this change would have persisted over time had she been there longer is hard to predict, but this example highlights the phenomenon of classroom dynamics, and the fact that despite demographic similarities, different groupings of students can result in different dynamics and behavior patterns.

CHAPTER 6 – DISCUSSION, CONCLUSIONS AND SIGNIFICANCE

Chapter Overview

In this chapter I discuss first the grounded theory model and its uses for research, practice, and policy; then, implications of the work, recommendations for teaching and learning, and strengths and limitations of the study.

6.1 Snowflake Metaphor

Scientists agree that no two snowflakes are alike—the crystalline make-up of each flake is different from every other flake. Yet snowflakes are made up of hydrogen, oxygen, and any atmospheric compounds that might be incorporated on the way down. Comparing snowflakes students in schools, is should not be difficult to agree that no two students are alike. Gene combinations and expression alone ensure that no two humans are the same, but that is compounded by infinite combinations of experiences, challenges, and opportunities that individuals can encounter. When 30 or so students come together in a classroom—the snowball perhaps—each unique individual connects and interacts with the others, resulting in a unique classroom setting. With this snowflake and snowball metaphor in mind, it seems unrealistic to find a solution that fits everyone.

Nonetheless, our job as educators is to engage students in meaningful learning activities that help them build understanding of the disciplines being taught. To do this successfully, it is useful to identify the generic structures and archetypes of educational systems. In doing so, common elements of classrooms, schools, and districts can be viewed in ways that best reveal leverage points for implementing change, and that best support teaching and learning. The grounded theory model

presented in Figure 14 identifies important elements involved in teaching and learning and the ways these need to be aligned and supported in order to build scientific literacy. This model is intended to provide a pragmatic tool that has use for research, practice and policy.

Throughout this research, pragmatism provided a methodological framework that allowed me to use an array of approaches suitable for understanding data available from the co-teaching experience. As a complement to pragmatism, systems thinking provided a lens to interpret small-scale, individual and small group interactions in the context of larger systems including the school and the education system. Grounded theory analyses and systems thinking concepts provided me with tools to create a model for understanding the complex interactions involved with teaching and learning. Throughout data collection, analysis, and interpretations, critical theory—grounded in social justice, linked to my own belief and passion—guided this work.

6.2 Review and Highlights of Grounded Theory

In line with the strength of mixed methods and pragmatism, different analyses using various data sets converged to support the grounded theory building process. Each analysis provided insights into student engagement, thinking, and learning in science, including the descriptive portion of the study, the grounded theory coding process, and personal reflections as a first year teacher and member of the school's culture. Empirical findings and observations enhanced existing knowledge from the literature representing past research in a variety of educational fields.

The study provided understanding of the tensions between the mainstream cultures of school and science, and the social, cultural, and linguistic backgrounds of students (see Atwater, 1994; Lee, O., 2005; Norman et al., 2001; Warren et al., 2001). Although research-based best practices can help overcome these tensions, the study highlighted the uniqueness of different classrooms, situations, and groupings of individuals, reinforcing the idea that one size does not fit all. The unique sociocultural assets of students in a given classroom need to guide the ways in which principles of teaching and learning are applied. Each situation provides a unique context, yet teaching and learning science in high-poverty, high-minority, urban schools is highly complex. The grounded theory model (Figure 14) provides a useful framework for investigating questions and addressing challenges in schools and educational systems.

The intention is for this model to be useful for teachers in the classroom, the educational research community, and policy-makers at different levels of the educational system. For research, the model can help build understanding of the complexities and interactions involved with teaching and learning, and can serve as a tool and framework for guiding research questions and identifying problems. For practice, the grounded theory model could be used as a professional development tool to help teachers understand the numerous factors that relate to students. It could be used to help facilitate professional learning opportunities, encouraging teachers to work collaboratively to better meet the learning and emotional needs of their students. Policy-makers could use the grounded theory model to comprehend the complexities of teaching and learning and to identify structures and policies that could better

support work in districts, schools, and classrooms. By better connecting the three—research, practice, and policy—the effectiveness and impacts of new policies could be researched as practitioners experience better support in the classroom.

6.3 Knowledge Claims and Leverage Points

6.3.1 Student Factors

Considering the concept of the leverage point, from systems thinking, students can be viewed as societal leverage toward ecological sustainability. To leverage education for impact on ecological sustainability, the educational system must achieve goals for science literacy.

A basic assumption going into this co-teaching and research experience was that contextualizing learning in the local environment would increase students' engagement in science; this evolved to become the study's central hypothesis. In general, the hypothesis was supported; however the findings provided interesting exceptions, as with field trip participation, and with resistance and reluctance.

Data from students participating in the study aligned with and supported findings from the research literature regarding intercultural tension. Similar to the Cultural Interface Zone described by Norman and colleagues (2001), I observed tension between the culture, language, and interaction styles that students brought to the science classroom, on the one hand, and the socio-cultural backgrounds of teachers (including myself), as well as the norms and practices of the school, on the other. Mainstream science and science teaching emphasize individual work and production of knowledge, using language that is concise, non-emotional and scientific, while

students from diverse backgrounds often respond better to more culturally sensitive approaches to teaching and learning, in which collaborative thinking, shared sense-making, and social constructivism dominate (e.g. Atwater, 1994; Lee, O., 2005; Warren et al., 2001).

Despite our teaching team's efforts to provide ongoing opportunities for collaborative student work, alternate forms of expression, and culturally relevant practice, still tensions prevailed, particularly related to behavior, movement, and noise levels in the classroom. The cultural factors that led to tension—movement and noise levels, in particular—were in close alignment with characteristics of Black Cultural Ethos described by Parsons (2008) and Boykin and Ellison (1995).

Findings from the descriptive portion of this study reinforced observations concerning the tension that existed, but also highlighted the unique natures of individual students and specific groupings of students. For example, I found the third period class to be the most challenging as a group, and field trip attendance and work completion rates (measures of engagement) validated these observations and intuitions. Analyses by class period challenged common stereotypes based on ethnicity or special education status. Measured using standard labels (e.g. ethnicity, special education), the three class periods were quite similar. The fifth period class had higher numbers of African American students and students identified with special educational needs, but it was the third period class that routinely challenged me as a teacher.

The primary student-level conclusion from this study is that each student is unique, and to help students reach their full potential, teachers need to differentiate

instruction and meet students where they are—based on prior knowledge, experience, and interests. Although this study focused on student data and outcomes, the main recommendations are related to teachers and teaching, and the systems and structures that support them. This makes sense since teaching can be viewed as the leverage point for supporting student success.

6.3.2 Teachers and Teaching

Laurence (2007) posed the question, “If teachers have answered the call to teach, how can we support them in this work?” (p. 76). The importance of training high-quality teachers (e.g. Penske & Haycock, 2006) has been well established, yet our educational systems have not yet perfected the means and structures to support teachers through their careers. Laurence summarized many of the factors related to teachers and teaching in her “reVisioning” model, which explains the ways that teachers navigate the decision-making process when considering whether to stay in or leave the profession. As represented by the “reVisioning currents” (p. 85), she described many of the teaching factors presented in the grounded theory model (Figure 14), such as growth, values, identity, beliefs, balance, health, success, environment, and needs (Laurence, p. 85).

As described by Laurence (2007), the educational system needs to support teachers through their entire career cycle, but particularly in their first four to ten years. Supports need to be better communicated to teachers so they are accessible, relevant, timely, and appropriate. One important component of the teacher support system should be partnerships between school districts and local universities.

Creating new partnerships and building upon existing relationship between universities and schools can help ensure that teachers have access to support throughout their careers. Universities already provide pre-service teachers to districts and in many cases provide ongoing professional development opportunities. Pre-service teachers can help bring a deeper level of reflection and action research to the classroom, while classroom teachers can provide their pre-service teaching partners with teaching strategies and meaningful experiences working with students. The pre-service and in-service teachers could operate as partners, working to make the curriculum as culturally relevant as possible. Furthermore, having an extra adult could make it easier to do more project work and group work, further supporting best practices.

Reflecting on my own experience as a first-year teacher has provided further credence to the notion of better support for teachers in the classroom. Although I did not come to teaching through a teacher education program, my alternative pathway prepared me in ways that were useful in the classroom; still, I quickly realized how much more experience I needed, and how many more skills, to be successful as a teacher. Coming from a background in science prepared me with substantial content knowledge. Additionally, through my doctoral work, I had developed a strong understanding—at a theoretical level—of culture and its role in learning. Nonetheless, I was overwhelmed by the practical challenges as a first year teacher, and I was surprised at how, as the year progressed, my theoretical beliefs and understandings seemed less accessible to me than when the year began. I routinely felt the tension

between my mainstream cultural position and the cultural backgrounds of students. Despite very intentional efforts to use culturally congruent teaching practices and activities, and to engage and connect with all students in meaningful, relevant ways, I fell short of my goals. Even when teachers want to engage students in meaningful work that is connected to their lives—i.e., culturally relevant education—they run into barriers at nearly every level.

The challenge of implementing culturally relevant, contextualized, and meaningful science learning in the classroom is a highly complicated and complex proposition. Simply juggling the time and organizational demands of good teaching is hard enough, particularly for a first year teacher. Throw into the mix the great diversity in the ways students express themselves and build understanding, in many cases displaying resistance and reluctance to learning in new ways, and the challenge can become daunting.

Building on the snowflake metaphor, we know that no two students are alike, and similarly, no two classrooms have the same dynamics and interactions. The grounded theory model presented in Figure 14 helps in identifying the generic structures involved with teaching and learning, and in simplifying the complexity of the system. As shown in the model, the goal is to achieve alignment among student factors, teachers and teaching practices, and the culture and climate of a school, and to provide flexibility for making adjustments in each particular situation. One of the clearest leverage points—a point in the system where we have the greatest opportunity for implementing positive change—is ensuring excellence in teaching.

6.3.3 School Culture and Climate

School culture and climate play a fundamentally important role in teaching and learning. The culture and climate of a school can—or may not—align with individual teacher’s values and teaching philosophies, support teachers as professionals, and, through leadership, help build a shared vision. When these and other aspects of school climate are addressed and attended to in ways that foster positive response, teachers are better supported in their work of educating students (see Dobbie & Fryer, 2009; McKinsey & Company, 2009).

Larger, systems-level factors affect teaching and learning in the classroom; school administrators can reduce the extent to which negative outside influences impact the classroom. In the context of this study, Carver had a strong administrative team that not only valued teachers, but also empowered them to develop a shared vision and strategy to obtain it. Molly Sharp (Assistant Principal) and James Monroe (Principal) made noticeable efforts to shelter teachers and students from outside factors that may have negatively affected teaching and learning. Nonetheless, to me as a teacher, it seemed that those outside factors still penetrated the shield these administrators established. It is hard to imagine how teachers and students make any progress towards learning goals in schools where the administration is not as strong and committed to supporting teaching and learning.

The findings in this study emphasize both the importance and difficulty of translating research-based teaching and learning into practice in an urban middle school environment. Every action and interaction that takes place in a school or

classroom is part of a larger, more complex system. To have lasting impacts, partnerships, programs, and curricular innovations must be implemented within a larger system of change.

6.4 Conclusions, Significance, and Recommendations

As noted by others in the literature (e.g., Marx et al., 2004; Penske & Haycock, 2006), many aspects of the educational system do not effectively support teachers and students in their efforts to increase scientific literacy and close achievement gaps. It would seem our educational system is in need of renewal, and in a time of economic and social flux, the opportunity for change is ripe. With limited resources, solutions must be innovative and effective, so that teaching practices in the classroom support learning. Practice should guide research questions, with research in turn further supporting practice. Similarly, research needs to inform policy-makers so they can build systems and structures to best support teachers and students.

The grounded theory model presented in Figure 14 describes the complex factors and interactions involved with teaching and learning, and shows how there must be alignment—harmony—among those factors for students to become engaged in science in ways that enable them to develop thinking skills and to learn with understanding. The grounded theory model can serve as a framework, to look more deeply at relationships and correlations among student engagement, thinking, and learning.

Another use of the model would be to identify leverage points where interventions can have the greatest positive impacts on teaching and learning. Relating

to students, the principal leverage point is guaranteeing that every student has the opportunity for high-quality teaching and learning—in other words, ensuring excellence in teaching. To leverage excellence in teaching, the system needs to support teachers throughout their careers, providing access to appropriate, timely opportunities for personal and professional growth (Laurence, 2007). Educational systems must do a better job of supporting teaching and learning if society is to achieve its goals for education, science education, scientific literacy, and ecological sustainability.

Consider, as an example of a leverage point, a potential change that has been discussed: to extend the school day and school year. In their recently released study on the impacts of the Harlem Children's Zone (HCZ) project, Dobbie and Fryer (2009) found that the extended school day and school year model of the HCZ, coupled with measures to ensure excellence in teaching, had significantly narrowed and in some cases eliminated testing gaps between White and African American students. These findings are impressive, and not surprising. Findings in this dissertation generally support such a notion—more school time, better time, and the potential impacts on quality of education. Extending the school day and school year could even make sense for our current society. The current model was based on America as an agrarian nation, when children were needed to help with chores and working in the fields. The U.S. is no longer an agrarian nation (though ironically, more people seem to be growing their own food); a new model for the school day and school year could reflect current societal demands—i.e., non-seasonal working families and knowledge of

learning lost over summer months. It should be noted that the model would still have to give due consideration to migrant and seasonally employed farm-working families, now in the minority.

If we were to extend the school day and school year, there would be more time and space at school for all the important aspects of childhood development such as art, music, physical education, and social and emotional development. As mentioned, teachers and students need breaks for renewal, reflection, and learning. In an extended school day/year model, there would still need to be blocks of time off during the school year, allowing students and teachers to have needed breaks. Nonetheless, the breaks would be dispersed throughout the school year so that students would not forget so much of what they had already learned.

Often teachers express feelings of isolation and frustration due to lack of time for planning and collaboration (Laurence, 2007; Laurence et al., 2006, 2007). In a new system, there could be time and space for teachers to work collaboratively to plan and implement research-based practices, and to further develop their skills in making learning more engaging and meaningful for students. These opportunities for professional growth could help close achievement gaps and build scientific literacy.

This new system could provide greater opportunities for parental involvement in schools. Working parents often have a hard time finding time to volunteer; however if the school day more closely matched the standard work day, parents might be able to adjust their schedules, allowing time to volunteer at their children's schools. Additionally, in the new system, parents who do not work outside the home and who

currently may spend more time with their children after school could spend some of that time in school working with individual students or groups of students.

Students especially could benefit from the new system. Currently, there is little time for anything but academic learning in schools, despite common knowledge that there is much more to developing healthy, happy individuals who can think critically and solve the problems of the world. In the new system, students would have more time for physical activities, social interactions and development, and time to simply play. They would also benefit from the increased number of caring adults involved with their schools.

Therefore, one system-level change could potentially provide time and space to put solid teaching and learning models into practice. The next step would then be to design necessary partnerships, programs, and curriculum. Of course, as with any change, there would be opponents and obstacles to overcome; however, the details of a solid design would address concerns and challenges to making change.

It is time for society to look at assumptions and biases about teachers and teaching. We have all heard the saying, “Those who can, do; those who can’t, teach.” Unfortunately, this underlying, societal assumption—the collective mental model about teaching—is also prevalent in our educational system and operations. Recognizing that this bias exists is a first step, but progress must be made toward changing it. Teaching is extraordinarily hard work, and doing it well requires deep commitment and ongoing, continual learning on the part of teachers (Ingersoll, 2001; Laurence, 2007). Teachers and teaching should be valued as one of the most important

professions in our society. Anyone who has ever parented knows how hard it is to raise strong, empowered, and wise children. Teachers have a similar responsibility to the young people of the nation and the world; in many cases, they are responsible for educating children who fall into the “school dependent” category. Society ignores this at its peril; through system improvement—perhaps through change involving chosen leverage points, such as extension of the school day and year—educational systems must provide teachers with the resources, structures, and systems to be as successful as possible.

6.5 Strengths and Limitations

Taking a systems-level approach to this work allowed me to synthesize and try to make sense of diverse and complex phenomena, and to offer ideas and solutions addressing some of our most pressing concerns as educators and environmental scientists. From my pragmatic perspective, a mixed methods research design was most appropriate, and provided me with a set of analysis tools to make sense of empirical data. By casting a broad net, I was able to provide insights that are useful for practice, research, and policy. The strength of my study arose from the convergence of understanding that arose from empirical findings and existing research. Nonetheless, as with any study, there are limitations and potential threats to validity and reliability.

A primary limitation of the study is found in the low numbers of students that participated from the overall pool. From approximately 90 students at the sixth grade level at Carver, only 37 returned informed consent and then participated. Although these students made up a fairly representative sample, a central tenet—that each

student has a unique story—would indicate that important information may not have been included in the analyses and findings. This was especially true when data were subdivided by ethnicity, resulting in numbers as low as two or three students for certain data sets. This limitation was minimized by the nature of the research design. Using a mixed methods approach allowed multiple data and analyses to converge upon findings and to build a deeper understanding of teaching and learning.

6.6 Final Words

In the Preface, I briefly described the ways our global, ecological system has been pushed far out of balance, potentially with devastating consequences. I also argued that the only way to solve ecological problems is to include educational systems as a fundamental element of the solution. Including and fixing educational systems is critical if we want to achieve our collective vision of ecological sustainability.

To do this, society must better utilize the public institutions that were created to educate and prepare citizens for their particular place and time. The educational system can no longer be isolated and kept separate from other public institutions. People of privilege—White middle-class families, specifically—need to ensure that ALL young people are equipped with the knowledge, understanding, and skills necessary to address global challenges. It is not enough for White, middle-class children to have educational success, because these children will not be able to solve the problems alone.

Fortunately, change is in the air and the time is ripe. The paradigm is shifting, and that gives hope. Just as this study has addressed cultural tensions in schools and science classrooms, at a more fundamental level it also points to tensions arising from the change process itself. Despite the best intentions of teachers, students, administrators, and families, inertia often conflicts with the change process, and when challenges are encountered, the tendency is for things to revert to the status quo. To overcome this systemic inertia, it will be necessary to build deep partnerships with solid structures to support new practices. The change process is similar to the process of turning a supertanker. Overcoming inertia requires significant and consistent energy; however, once the supertanker begins to turn, inertia is replaced with momentum, resulting in a nearly unstoppable force.

It is time to make meaningful changes in the education system so we can build a scientifically literate population, empowered with the knowledge and skills necessary to achieve ecological sustainability. This study provides system-level insights that can support changes necessary to support excellence in teaching, relevance in research, and ultimately a better educational experience for young people in our community.

EPILOGUE

More than two years after the research for this dissertation was concluded, change has continued to occur at the George Washington Carver Magnet School. Principal James Monroe remained at Carver one year after the magnet grant ended (2007-08) and then moved to a local high school (2008-09), his presumed last tenure before retirement. Assistant Principal Molly Sharp left the state in the year following the end of the magnet grant to become Assistant Superintendant of Instruction for a large urban district in the Midwest. Ms. Irving, the language-arts/social studies teacher who was my co-teacher, retired at the end of our year of co-teaching (2006-07, the year of the study), while Ms. Gutierrez, the math teacher with whom I co-taught the third period class, took maternity leave (March 2007 through January 2008), and returned to Carver for the remainder of the 2007-08 school year, but then transferred to a suburban district closer to her home for the start of the 2008-09 school year. Several other teachers who seemed to be leaders at the school remained, while others have since left, a trend that reflects Carver's history of high staff turnover. From the university's standpoint, the three Master's-level students involved in the study have recently completed their theses; one is working as a community-based educator, one has returned to the sciences, and the third is finishing a teacher education program to become a licensed high school science teacher. As for me, I will continue working toward the goals of educational justice and ecological sustainability.

REFERENCES

- Albert Einstein. (n.d.). Retrieved May 8, 2009, from Quotes.net at <http://www.quotes.net/quote/9285>.
- American Association for the Advancement of Science. (1989). *Science for all Americans*. New York: Oxford University Press.
- Atwater, M. M. (1994). Research on cultural diversity in the classroom. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning project* (pp. 558-598). New York: Macmillan.
- Atwater, M. (1996). Social constructivism: Infusion into the multicultural science education research agenda. *Journal of Research in Science Teaching*, 33, 821-37.
- Boykin, W. A., & Ellison, C. M. (1995). Multiple ecologies of Black youth socialization: An Afrographic analysis. In R.L. Taylor (Ed.), *African American youth: Their social and economic status in the Unites States* (pp. 93-142). Praeger: Wesport, CT.
- Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school*. (Expanded edition). Washington, DC: National Academies Press.
- Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18(1), 32-42.
- Caine, R., & Caine, G. (1991). *Making connections: Teaching and the human brain*. Alexandria, VA: Association for Supervision and Curriculum Development.
- Caine, R., & Caine, G. (1997). *Education on the edge of possibility*. Alexandria, VA: Association for Supervision and Curriculum Development.
- Caskey, M. M., & Anfara, V.A., Jr. (2007). NMSA research summary: Young adolescents' developmental characteristics. In M. M. Caskey (Ed.), *Middle level education research annual: Engaging young adolescent learners*, (pp. 1-9). Westerville, OH: National Middle School Association.
- Cole, M. (1996). *Cultural psychology: A once and future discipline*. Cambridge, MA: Harvard University Press.

- Corbin, J., & Strauss, A. (2008). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (3rd ed.). Thousand Oaks, CA: Sage.
- Creswell, J. W. (2008). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (3rd ed.) Upper Saddle River, NJ: Pearson Education.
- D'Aundre, R. (1996). Some propositions about the relations between culture and human cognition. In J. W. Stigler, R. A. Schweder, & G. Herdt (Eds.), *Cultural psychology: Essays on comparative human development* (pp. 65-129). Chicago: Cambridge University Press.
- Dobbie, W., & Fryer, W. G., Jr. (2009). Are high-quality schools enough to close the achievement gap? Evidence from a bold experiment in Harlem. Harvard University. Retrieved, June 1, 2009, from <http://www.economics.harvard.edu/faculty/fryer/files/hcz%204.15.2009.pdf>.
- Grigg, W., Lauko, M., & Brockway, D. (2006). *The nation's report card: Science 2005*, NCES 2006-466. U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.
- Gutierrez, K., & Rogoff, B. (2003). Cultural ways of learning: Individual traits or repertoires of practice. *Educational Researcher*, 32(5), 19-25.
- Jencks, C., & Phillips, M. (1998). The Black-White test score gap: An introduction. In C. Jencks & M. Phillips (Eds.), *The Black-White test score gap* (pp. 1-51). District of Columbia: Brookings Institute.
- Johnson, R., & Onwuegbuzie, A. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, 33(7), 14-26.
- Ingersoll, R. (2001). Teacher turnover and teacher shortages: An organizational analysis. *American Education Research Journal*, 38, 499-534.
- Kelley, S., Miller-Jones, D., & Becker, W. (2009a, April). Investigating student engagement, thinking, and learning in science—Findings from a yearlong, inquiry-based teaching experience. Paper presented at the Annual Meeting of the National Association of Research in Science Teaching, Garden Grove, CA.
- Kelley, S., Miller-Jones, D., & Becker, W. (2009b, April). Students and teachers navigating cultural conflicts in the classroom to support engagement and

learning in science – A grounded theory. Paper presented at the Annual Meeting of the American Educational Research Association, San Diego, CA.

- Kelley, S., Miller-Jones, D., & Becker, W., (2008, March). Theory to practice, practice to theory: Building a substantive grounded theory addressing how inquiry-based learning and teaching impacts students' engagement and learning in science. Poster session at the Annual Meeting of the National Association of Research in Science Teaching, Baltimore, MD.
- Krathwohl, D. (2002). A revision of Bloom's Taxonomy: An overview. *Theory into Practice*, 41, 212-218.
- Lambert, N. M., & McCombs, B. L. (1998). *How students learn: Reforming schools through learner-centered education*. Washington DC: American Psychological Association.
- Laurence, W. (2007). Revisioning: A theoretical model of teachers' career choices. Dissertation, Portland State University.
- Laurence, W., Kelley, S., Becker, W., & Day, S. (2007, April). Navigating critical junctures: Collaborating to support teachers' learning as they refine their practice to include technology-enhanced scientific inquiry. Paper presented at the Annual Meeting of the American Education Research Association, Chicago, IL.
- Laurence, W., Kelley, S., Becker, W., Day, S., & Marshall, C. (2006, January). Time to learn inquiry: Exploring teachers' learning as they refine their practice to include technology-enhanced scientific inquiry. Paper presented at the Annual Meeting of the Association for Science Teacher Educators, Portland, OR.
- Lee, C. D. (1998). Culturally responsive pedagogy and performance-based assessment. *Journal of Negro Education*, 67, 269-279.
- Lee, O. (2005). Science education with English language learners: Synthesis and research agenda. *Review of Educational Research*, 75, 491-530.
- Lemke, J. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, 38, 296-316.
- Lemke, M., & Gonzales, P. (2006). *U.S. student and adult performance on international assessments of educational achievement. Findings from the Condition of Education, 2006*. NCES 2006-073. U.S. Department of Education, National Center for Education Statistics. Washington D.C: U.S. Government Printing Office.

- Levine, D. (1994). Instructional approaches and interventions that can improve the academic performance of African American students. *Journal of Negro Education*, 63, 46-63.
- Lovelock, J. (1988). *The ages of Gaia—A biography of our living Earth*. New York, NY: Norton.
- Lynch, S. (2001). "Science for all" is not equal to "one size fits all": Linguistic and cultural diversity and science education reform. *Journal of Research in Science Teaching*, 38, 622-627.
- Madhere, S. (1998). Cultural diversity, pedagogy, and assessment strategies. *Journal of Negro Education*, 67, 280-95.
- Marx, R. W., Blumenfeld, P. C., Krajcik, J. S., Fishman, B., Soloway, E., Geier, R., et al. (2004). Inquiry-based science in the middle grades: Assessment of learning in urban systemic reform. *Journal of Research in Science Teaching*, 41, 1063-1080.
- Marzano, R. J. (1992). *A different kind of classroom: Teaching with dimensions of learning*. Alexandria, VA: Association for Supervision and Curriculum Development.
- Madhere, S. (1998). Cultural diversity, pedagogy, and assessment strategies. *Journal of Negro Education*, 67, 280-295.
- McKinsey & Company (2009). *The economic impact of the achievement gap in America's schools*. Social Sector Office. Retrieved June 1, 2009, from www.mckinsey.com/clientservice/socialsector
- National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.
- National Research Council. (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: National Academy Press.
- National Science Teachers Association (2003). *Beyond 2000 – Teachers of science speak out: An NSTA lead paper on how all students learn science and the implications to the science education community*. Retrieved July 31, 2008, from <http://www.nsta.org/about/positions/beyond2000.aspx>
- Norman, O., Ault, C. R., Jr., Bentz, B., & Meskimen, L. (2001). The Black-White "achievement gap" as a perennial challenge of urban science education: A

- sociocultural and historical overview with implications for research and practice. *Journal of Research in Science Teaching*, 38, 1101-1114.
- Northwest Regional Educational Laboratory. (2007). *Portland Public Schools Jefferson Cluster Magnet Program, Final evaluation report*. Portland, OR: NWREL.
- Parsons, E. C. (2008). Learning contexts, Black Cultural Ethos, and the science achievement of African American students in an urban middle school. *Journal of Research in Science Teaching*, 45, 665-683.
- Penske, H. G., & Haycock, K. (2006). *Teaching inequality—How poor and minority students are shortchanged on teacher quality*. Washington, DC: The Education Trust.
- Qualls, A. L. (1998). Culturally responsive assessment: Development strategies and validity issues. *Journal of Negro Education*, 67, 296-301.
- Rivergate School District. (2006). Achievement data. Retrieved October 1, 2006 from <http://www.pps.k12.or.us/depts-c/rne/results/2008/index.php>
- Rivergate School District. (2008). Achievement data. Retrieved March 23, 2008, from <http://www.pps.k12.or.us/depts-c/rne/results/2008/index.php>
- Rivergate School District. (2009). Achievement data. Retrieved May 11, 2009, from <http://www.pps.k12.or.us/depts-c/rne/results/2008/index.php>
- Rodriguez, A. J. (1998). Strategies for counterresistance: Toward sociotransformative constructivism and learning to teach science for diversity and for understanding. *Journal of Research in Science Teaching*, 35, 589-622.
- Waters Foundation (2009). *Systems Thinking in Schools—A Waters Foundation Project*. Materials and resources—tools, concepts, and habits of a systems thinker. Retrieved June 1, 2009, from <http://www.watersfoundation.org/index.cfm?fuseaction=materials.main>
- Tate, W. F. (1995). Returning to the root: A culturally relevant approach to mathematics pedagogy. *Theory into Practice*, 34, 166-173.
- U.S. Department of Education, National Center for Educational Statistics. (2006). *The condition of education 2006* (NCES 2006-071). Washington, DC: U.S. Government Printing Office.

- Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A., & Hudicourt-Barnes, J. (2001). Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching*, 38, 529-52.
- Webb, N. L. (2005). Web alignment tool. Retrieved February 2, 2006, from University of Wisconsin, Madison, Wisconsin Center for Educational Research Website: <http://www.wcer.wisc.edu/WAT/index.aspx>
- White, B., & Frederiksen, J. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction*, 16(1), 3-118.

APPENDICES

Appendix A – School Artifacts Relating to Cultural Proficiency and Systems

Thinking

Appendix B – Artifacts from Sixth Grade Science Curriculum

Appendix C – River School Lessons and Curricular Connections

Appendix D – Level of Thinking Artifacts

Appendix E – Student Focus Group Protocol

Appendix F – Themes from Phase One of Grounded Theory Analysis

APPENDIX A

School Artifacts Relating to Cultural Proficiency and Systems Thinking

Agenda from Cultural Proficiency Institute

Magnet Planning Process and Program Development

Habits of a Systems Thinker Diagram

George Washington Carver Professional Learning Community

Agenda—August 21-24, 2006

Designing a Better Future...for Ourselves, Our Community, Our World

Day One: Monday, August 21

Theme — Clarifying our Vision & Building Community Capacity

- 8:30 Continental breakfast and “Nametags”
- 9:00 Welcome, Purpose & Plan, Introductions, Overview of Session
- 9:30 Teamwork: Creating a representation of GW Carver’s vision — drama, music, dance, technology, visual, combination or other
- 10:15 Break
- 10:30 Work on presentations
- 11:15 Team presentations
- 12:00 Lunch
- 1:00 Processing the vision presentations—4 corners
- 1:15 How to make a vision a reality: Change [CBAM], Commitment, and Cultural Proficiency [T-chart with change & concerns]
- 2:00 Professional Learning Community information/activity: Reinforce importance, introduce processes, announce requirements
- 2:30 Processing the Learning: What behaviors need to change in order to achieve the vision?
- 2:45 Break
- 3:00 BARNGA: Cultural Play that engages staff and unpacks unspoken behaviors that affect school culture.
- 4:00 Closing Reflections—Reminder of homework readings

Day Two: Tuesday, August 22

Theme: Clarifying Our Vision & Building Community Capacity

- 8:30 Continental Breakfast and Conversations
- 9:00 Feedback from Day One—Dyad Reflections: What will help you be your best self today? What might get in the way of your being your best self today?
- 9:30 Moving from Knowledge to Practice: Jigsaw of Readings
- 10:30 Break
- 10:45 What does Cultural Proficiency mean to you? What is Culturally Proficient Instruction?
- 12:00 Lunch
- 1:00 Reconnecting: Equity Tide and Dyad Response
- 1:20 Examining Instructional Practices: Video Dialogue: Lesson viewing and analysis: Transferring knowledge to practice
- 2:30 Posting Insights for Gallery Walk

- 2:45 Break
- 3:00 Gallery Walk: PLC Consultancy: What action steps must I take in order to provide culturally proficient instruction to every student every day?
- 4:00 Closing Reflections

Day Three: Wednesday, August 23

- 8:30 Continental Breakfast: Gathering and Conversation
- 9:00 Feedback from Day Two—Dyad Reflections: What do you hope happens in today's sessions? What do you hope does not happen in today's sessions?
- 9:30 Redesigning lessons for culturally proficient instruction: Teams work on a prepared lesson
 - Select one lesson to modify
 - Redesign lesson based on prior experience
 - Each team briefly shares lesson
- 10:45 Break
- 11:00 Team Presentation of Prepared Lessons
- 11:45 Processing the lessons work & transferring knowledge to practice
- 12:00 Lunch
- 1:00 Reconnecting
- 1:20 30 Adaptable Strategies for K-8 Classrooms
- 1:40 Sharing Strategies across the Professional Learning Community
- 2:45 Break
- 3:00 What will change require? Identifying individual/team/school essentials for change
- 4:00 Closing reflections

Day Four: Thursday, August 24

Closing the Knowing/Doing Gap: A Culturally Proficient Learning Community

- 8:30 Continental Breakfast: Gathering and Conversation
- 9:00 Feedback from Day Three—Dyad Reflections: How would you describe your own learning experience during this week?
- 9:30 Focusing on Teaching and Learning
- 10:45 Break
- 11:00 Video Dialogue: Successful PLCs that improve teaching and learning
- 11:45 Processing the morning
- 12:00 Lunch
- 1:00 Reconnecting: Using technology and Dyad response
- 1:20 Developing Team Plans for Staying the Course
- 2:45 Break
- 3:00 Here's What/So What/Now What—PLC Consultancy: What action steps will we take in order to provide culturally proficient school that accomplishes our vision?
- 4:00 Closing Reflections

Magnet Planning Process and Program Development

Cluster-wide Magnet Program Development

Stage I Structural Focus Spring 05 - Fall 05	Stage II Refinement Focus Fall 05—Summer 06	Stage III Expanding and Sustaining Focus Fall 06—Fall 07
Shared Vision/Commitment
Program Components	Refine Integration/Alignment	Increase Integration/Alignment
Schedule and Staffing	Adjustments/Skill Building	Increase Specialization
Essential Equipment/Materials	Specialized Equipment/Materials	Increase Integration
Identify Experts/Partners	Engage Experts/Partners	Expand as Appropriate
Initiate Publicity	Refine Publicity	Expand Publicity

157 Professional Development Alignment

Unaware of skills and strategies required	Aware Knows Skills or strategies are required	Conscious Competence Can implement skills or strategies in a planned, guided, conscious manner	Unconscious Competence Can implement skills or strategies as needed. Can create innovative uses and/or versions of skills or strategies as appropriate. Uses skills or strategies as a "habit," second nature.

Habits of a Systems Thinker Diagram

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APPENDIX B

Artifacts from Sixth Grade Science Curriculum

Key Concepts

Curriculum Map

Sample Lesson Plans

Sample Quizzes

Example of Student Scoring Guide

Key Concepts

Key Concepts for Sixth Grade Science:

1. Characteristics of life
2. Cells – plant, animal, bacterial
3. Cells, tissues and organ systems – structure, functions and interactions
 - a. Relationship to habitat
 - b. Changes in cycles and trends
 - c. System inputs and outputs; cause and effect
4. Photosynthesis
 - a. Change in cycles and trends
 - b. System inputs and outputs
5. Change over time
 - a. Understanding of cells and microbes
 - b. Understanding of heredity
 - c. Diversity, adaptation, speciation, extinction
 - d. System inputs and outputs
 - e. Cause and effect
6. Reproduction – Sexual and asexual
7. Roles of genetics and environment on traits
 - a. Cause and effect
8. Patterns of heredity
9. Ecosystems
 - a. Balance and interdependence
 - b. Sunlight and energy flows; food webs
 - c. Functions of organisms and populations
 - d. Organism relationships (predator-prey, etc.)
 - e. Niches and competition
 - f. Changes in cycles and trends
10. Biodiversity
 - a. Random variations and natural selection
 - b. Adaptations to environmental change
11. Science Inquiry
 - a. Ask questions/form hypotheses
 - b. Design experiments to answer/test – variables
 - c. Data collection (technology)
 - d. Analysis and summary (technology)

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	Proposed "Spiraling" Curriculum - 9/20/06	
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Lesson Plan Format

Date: November 14-15, 2006 Subject: Science Topic: Building Inquiry/Process skills

Student Objectives

By the end of this lesson, my students will be able to...

- Identify the basic concepts of experimental design
 - Hypothesis
 - Dependent variable
 - Control group
 - Independent variable
 - Constants
 - Repeated trials

Opening Activity/Introduction

(Includes students' active participation and links to prior knowledge)

- Hand out paper, write names, fold paper air plane

There really isn't much to this, because the activity is intended to help student identify the basic components of experimental design.

Teaching the New Objective

(Outline of activities, good questions to pose, major points, etc.)

In science room

- Once airplanes are built, tell students we're going to go into the hall to find out whose design is the best.
- I'll say, "Ready? One, two, three...wait, how are we going to know whose plane is the best?" We'll record the ideas on the overhead.
- Additional questions: "Which criterion would be the hardest to measure?... Which would be the easiest? ... Which would be the best?... Why?"
- Decide on which criterion to measure (we're going to settle on distance traveled...question – total distance or first touch on the ground)
- Then we'll go out into the hallway and take turns tossing the planes and measuring how far they traveled...probably have 5 people throw at a time, everyone else will sit along the lockers.
- After everyone has flown their planes, we'll go back into the room and they can add tape, paper clips, refold or another modification. (Depending on how the hallway process goes, we might have students go back into the science room once they have flown their planes.)

- Have a brief (controlled) discussion about why they made their changes. Introduce the concept of hypothesis... “If I ...then...” (e.g. If I add a paper clip to the nose of my plane, then it will fly farther)
- Have each student write his/her hypothesis on the data sheet.
- Before going back into the hall, ask “Is throwing our planes one time a fair way to determine which is best? Why or why not?”
- Lead students to idea that repeated trials give more reliable results because it reduces the effects of chance errors (drafts of air, a bad toss, etc.)
- Go back into the hall and let each student throw his/her plane several times, measuring the distance each time.
- Back in the class, use the leading questions:
 - How did you act on your plane? (refolded, added paper clips, added tape...) Talk about modified, altered, varied...
 - What did you purposely change about your plane? (the wing shape, the center of gravity, the weight of the plane...)
 - How did you determine your plane’s response? (flight time, distance, straight travel...)
 - What remained the same about your plane? (Constants – size of paper, texture of the paper, weight of the paper...)
- Fill out table as whole group
- Introduce the term variable – each factor that changed.
 - Independent variables – purposely changed or manipulated
 - Dependent variables – responding variables
 - Constants – variable that were controlled or stayed the same
- Ask how we know that the changes we noticed are from our modifications, not unaccounted factors such as air flow from doors, heaters, etc.
 - Concept of Control (teacher’s unchanged plane)

Closing Activity

(Includes students’ active participation, reviews lesson, and relates to objective)

- Introduce the Experimental Design Diagram (p. 14)
- Have each group decide how to fill out the form
- As a whole group, fill it out as practice. Mention that we will be using this template many more times.

Assessment *(How did the lesson go?)*

1. Did the students learn and how do you know?

2. Self-assessment: What went well and what would you change?

Materials/Room Arrangement

Provisions for Individual Students

Lesson Plan Format

Date: 12/6/06-12/7/06 Subject: 6th Grade Science Topic: Heart Rate Lab for Anchor Papers

Student Objectives (To meet Anchor Assignment requirements and have sound experimental design...)

By the end of this lesson, my students will be able to...

- ☐ Measure heart rate
- ☐ Have sufficient data to complete anchor assignment

Opening Activity/Introduction

(Includes students' active participation and links to prior knowledge)

- ☐ Share what they have learned from internet research
- ☐ Describe task – anchor requirements – to get a 4, you need to investigate multiple (at least 3 activities)

Teaching the New Objective

(Outline of activities, good questions to pose, major points, etc.)

- ☐ Practice measuring heart rate – everyone will calculate their average resting HR (measure 5 times)
- ☐ Reconvene – share out – get class average too (put into Excel)
- ☐ Brainstorm exercises and get consensus on three to investigate
- ☐ Make hypotheses
- ☐ Identify independent variable, dependent variable, constants, control and number of trials
 - Individually → IV = type of exercise; DV = change in HR
 - As Class → IV = different students (same regime); DV = variations in HR by ...(gender? Age? Eye color?)
- ☐ Agree on procedure
- ☐ Assign group roles and tasks (rotate – ideally everyone will go through exercise regime...may not have enough time) **OR**
- ☐ **Have everyone measure their own HR and go through entire regime as a group**

Closing Activity

(Includes students' active participation, reviews lesson, and relates to objective)

- ☐ Determine how far we got
- ☐ What have you discovered so far? (Record on computer)
- ☐ What still needs to be done? Next steps?

Homework:

Work on first draft of introductory paragraph

<ul style="list-style-type: none"> ❑ Define heart rate ❑ Describe how to measure it
<p>Assessment (<i>How did the lesson go?</i>)</p> <p>3. Did the students learn and how do you know?</p> <p>4th Period – 12/6/06</p> <ul style="list-style-type: none"> ▪ Most learned how to measure heart rate – they got reasonable numbers ▪ Will have to wait until they finish the lab on Monday and beyond to see what they really learned ▪ <p>4. Self-assessment: What went well and what would you change?</p> <p>4th Period – 12/6/06</p> <ul style="list-style-type: none"> • Needs faster pace – at beginning at least • Brainstorm ideas, but don't necessarily give them so many options – don't write up inappropriate choices • Finding and measuring pulse takes a long time • Demonstrate calculations – i.e. multiplying by 4; dividing by 5 – review what are appropriate rates • Skills that were obstacles – multiplying by 4
<p>Materials/Room Arrangement</p>
<p>Provisions for Individual Students</p>

Sample Quizzes

Photosynthesis and Respiration Quiz

Fill in the blank:

1. The _____ is the organelle where photosynthesis takes place.
2. The process of _____ is responsible for producing most of Earth's oxygen.
3. An organism that makes its own food is called a(n) _____.
4. The first stage of respiration takes place in the cytoplasm. The second stage takes place in the _____.
5. Carbon dioxide enters the plant through small openings on the underside of leaves called _____.
6. Fermentation provides energy for cells without using _____.
7. When you do hard exercise for a long time, the cells in your body go through the process of fermentation to provide energy to your muscles. As a result, _____ builds up in your muscles and makes you feel sore.

Word Bank:

Stomata	Photosynthesis	Heterotroph	Chloroplasts	
Lactic acid	Mitochondria	Oxygen	Autotroph	Carbon
dioxide	Respiration	Cell wall	Glucose	Fermentation
Yeast				

The following two equations represent photosynthesis and respiration. Label each equation as photosynthesis or respiration.

Explain the difference between heterotrophs and autotrophs.

BONUS: Explain how energy flows through ecosystems. Think about the sun, autotrophs, heterotrophs, plants, animals, photosynthesis and respiration.

Here are some students' ideas for science inquiry topics. Choose one and create a question that can be answered through a scientific investigation. This will be your science inquiry work sample.

Without Vernier probes:

Investigate how different colors affect photosynthesis

Using Vernier probes:

CO₂ Sensor

- Investigate how fast different plants use up CO₂
- Compare CO₂ outside and inside
- Compare CO₂ of dry pea seeds vs. soaked seeds
- Comparing CO₂ levels in different rooms
- How number of people affect CO₂ levels

Temperature Probe

- Comparing the normal temperature of humans
- How the temperatures in the fish tanks compare over time
- How different liquids cool
- Comparing water temp from different taps
- How sunlight affects temperature
- How temperature compares in different rooms

Heart Rate Monitor

- See the effects of exercise on HR
- How fast your heart rate recovers after activity
- See how drinking cold water affects heart rate
- Compare heart rate before and after drinking an energy drink, or eating a candy bar, drinking a soda...
- Compare a.m. HR to p.m. HR
- Monitor HR while holding breath
- Compare boys v. girls HR

- Compare students with teachers HR (adult/child)
- Compare HR sitting vs. standing
- How different emotions affect HR

The topic I have chosen is...

My question is...

Quiz on Cells and Macroinvertebrates

6th Grade Science

1. The development of the microscope allowed scientists to discover cells. Many experiments and observations over time led to the development of the "Cell Theory." Cell theory states 3 things. Please list them below.

- a. _____

- b. _____

- c. _____

2. The brain is to a body as the _____ is to a cell.
3. The _____ are often referred to as the "powerhouses" of cells because they provide energy for cells.
4. The _____ are only found in plant cells, and are the location where photosynthesis takes place.

Word Bank for questions 2, 3 and 4:

Vacuole, Nucleus, Endoplasmic reticulum, Chloroplasts,
Golgi bodies, Mitochondria, Lysosomes, Ribosomes

In the following section, match the correct definition listed on the right to each term listed on the left.

_____ Carbohydrates	A: An organic molecule that cells use to store energy - like a bear storing extra fat to get through the winter
_____ Proteins	B: A type of protein that speeds up a chemical reaction - like saliva breaking crackers down into simple sugars
_____ Lipids	C: The movement of molecules from an area of high concentration to low concentration
_____ Enzyme	D: The movement of molecules across a membrane that requires cells to use energy - can move molecules from an area of low concentration to high concentration
_____ Osmosis	E: Energy-rich organic compounds such as sugars and starches
_____ Diffusion	F: Large organic compounds that are the "building blocks" for things like hair and fingernails
_____ Active transport	G: The diffusion of water molecules across a membrane that moves from high concentration of water to a low concentration of water

Figure 1.

Is this a picture of a plant cell or an animal cell? Explain how you know.

Using the knowledge and skills they learned at Winter Ponds, GW Carver students decided to investigate a new water body. They collected macroinvertebrates, including at least one of each of the species shown below in the box. Using this field data, please complete the data sheet on the back of this page and indicate whether the water body is Excellent, Good, Fair or Poor.

A large, empty rectangular box with a black border, intended for students to record their field data on macroinvertebrates.

Based on this experience, could you say that this water body always has the rating you just gave it? Why or why not?

BONUS QUESTION: Do you think this water body is a river or a pond? Please explain.

Science Inquiry Work Sample – Writing Checklist

Introduction:

Forming Question & Hypothesis:

In a paragraph, explain your question and hypothesis. Make sure to include the following:

- ☐ Is your idea written as a question that can be tested with a scientific investigation?
- ☐ Are your question and hypothesis written clearly so the reader understands what you are trying to find out?
- ☐ Have you written what you already know – your background knowledge and/or experiences? Have you explained how what you already know helped you make your hypothesis?

Designing the Investigation:

Materials:

List your materials (as a bulleted list – not a paragraph)

Procedure:

In a paragraph

- *Briefly summarize your experiment (we investigated how jumping jacks affected heart rate...we investigated how sunlight affected CO₂ levels...)*
- *Explain what you changed in your investigation (your independent variable), what data you were collecting (your dependent variable) and things that stayed the same (the constants)*
- *Also explain any other observations that you recorded (if any).*

List (as numbers... 1. 2. 3. etc.) the steps you took to complete your investigation. Be sure to include enough information that someone else could do your experiment again.

Checklist:

- ☐ Have you included all the materials that you used?
- ☐ Are your procedures detailed enough for someone new to run your experiment? Since you have already run the experiment, is there anything more you need to add?
- ☐ Did you tell what data and observations you collected during the experiment?

Data / Collecting and Presenting Data:

Include your data tables and graphs from your investigation. Make a new table (and graph) that helps summarize your data. You could include the maximum level, the mean, or perhaps the amount of change you noticed over the testing period. Include data that makes sense and that will help you answer your question.

Checklist:

- ☐ As you carried out your investigation, did you record measurements and observations that might help you answer your question and/or test your hypothesis?
- ☐ Did you design or include a data table with your measurements and/or observations?
- ☐ Did you transform your measurements or observations to make them easier to understand (i.e. making graphs, reorganizing, doing calculations, etc.)

Discussion and Conclusion / Analyzing and Interpreting Data:

In a paragraph, write sentences that explain your data (for example: The mean CO₂ level in the hallway was 200 ppm. The temperature of milk changed a tenth of a degree faster than water per second. Standing on one leg made the heart rate of everyone in our group increase by an average of 10 bpm. Also include any patterns or interesting things you notice from your data.

In another paragraph, explain whether or not your experiment has helped to answer your question. Did it support (or not) your hypothesis? Now that you have run your experiment, what information do you wish you had? If you were going to run this or a similar experiment again, how would you change it? What are some sources of error or confusion in your experiment?

Checklist:

- ☐ Did you report the results from your investigation?
- ☐ Did you identify any patterns that you see and try to explain those patterns? Did you use science concepts and language in your explanations?
- ☐ Did you explain how the experiment answered or didn't answer your question?
- ☐ Did you use evidence to explain if your hypothesis was supported or not?
- ☐ Did you review your investigation for possible errors in measurements or observations? What are the limitations of your conclusions – what can you say, and what do you still need more information to be able to say?

APPENDIX C

River School Lessons and Curricular Connections

River School Lessons with Connections to Standards

River School Schedule

River School Classroom Lessons Connections to Standards 2007-08

- ***What is a Watershed?***- grades K-12.
 - U2. Identify a system's components, its **inputs and outputs**, and describe **cause and effect** relationships within the system
 - U3. Use a **conceptual model** to make predictions and inferences about familiar and unfamiliar phenomena in the natural world.
 - S2. Describe how daily choices of individuals, taken together, affect global cycles, ecosystems, and natural resource supplies.
- ***Water Cycle***- grades 3-8.
 - E2b. Explain the water cycle.
 - E2d. Identify factors that affect the rate of evaporation, condensation, and cloud formation.
 - U1. Identify and explain patterns of change in **cycles and trends**.
- ***Who Polluted the Slough?***- grades 5-12.
 - U2. Identify a system's components, its **inputs and outputs**, and describe **cause and effect** relationships within the system.
 - U4. Identify and explain evidence of physical and biological **changes over time**.
 - S1. Analyze the relationship between science, technology and values in personal and community decision making.
 - S2. Describe how daily choices of individuals, taken together, affect global cycles, ecosystems, and natural resource supplies.
 - S3. Explain the effect of large-scale human activity on natural systems.
- ***Water Chemistry***- grades 4-12.
 - P1a. Describe how to measure characteristic properties including boiling and melting points, solubility, and density.
 - P2a. Distinguish between examples of chemical changes and physical changes.
 - P2d. Recognize that substances may be grouped by their physical properties.
- ***Macroinvertebrates***- grades 5-12.
 - L4. Identify and describe factors that influence the balance and interdependence of populations of organisms in an ecosystem.
- ***Wetland Plants***- grades 4-8; and
- ***Riparian Plants***- grades 2-12.
 - L2. Describe and explain the structures, functions, processes and relationships within organisms in terms of cells, tissues, organs and organ systems.
 - L2c. Recognize how structural differences among organisms at the cellular, tissue, and organ level are related to their habitat and life requirements.

- L5b. Describe how animal and plant structures adapt to environmental change.
- ***Habitats of our Ecosystem-*** grades 2-8.
 - L4. Identify and describe factors that influence the balance and interdependence of populations of organisms in an ecosystem.L4a. Identify that sunlight is the major source of energy in most ecosystems and that energy then passes from organism to organism in food webs.
 - L4b. Identify populations of organisms within an ecosystem by the function that they serve.
 - L4c. Differentiate between relationships among organisms including predator-prey, producer-consumer, and parasite-host.
 - L4d. Explain the importance of niche to an organism's ability to avoid direct competition for resources.
 - L5. Describe and explain diversity, adaptation, and change over time of organisms as demonstrated by the fossil record, common ancestry, speciation, adaptation, variation, and extinction.
 - L5b. Describe how animal and plant structures adapt to environmental change.
 - U5. Identify and describe **structure and function** at various levels of organization in life, physical, and earth and space science.
- ***Water Bugs-*** grade K-4.
- ***Animal Signs and Tracking-*** grades 4-12.
- ***Birds of the Columbia Slough-*** grades 4-12.
- ***Bird Migration-*** grades 5-12.
- ***Wetland Introduction-*** grades 4-12.
- ***Ethnobotany: Traditional uses of our local plants-*** grades 2-8.
- ***Animal Adaptations-*** grades K-8.
- ***Microworlds-*** grades 3-6.
- ***Groundwater-*** grades 2-8.
- ***Fish Biology-*** grades K-12.
- ***Soil Science-*** grades 6-12.
- ***Invasive Plants & Animals-*** grades 4-12.
- ***Food Webs-*** grades 4-8.

Our mission:
To foster action to protect, enhance, restore and revitalize
the River and its watershed.

River School Education Program

Proposed Outline for GW Carver, 6th Grade, 2006-07

Class One: What is a Watershed? / Pre-tests

Oct 18, 2006	10:40-11:32
	12:15-1:07
	1:10-2:02

Class Two: Water Chemistry

Nov. 8, 2006	10:40-11:32
	12:15-1:07
	1:10-2:02

Field Trip to Winter Ponds Environmental Learning Center:

Water Chemistry/Watershed model

Nov. 29, 2006	AM
	PM
Nov. 30, 2006	PM

Class Three: Water Cycle

Dec 13, 2006	10:40-11:32
	12:15-1:07
	1:10-2:02

Class Four: Wetland Introduction

Jan. 3, 2007	10:40-11:32
	12:15-1:07
	1:10-2:02

Class Five: Wetland Plants

Jan 17, 2007	10:40-11:32
	12:15-1:07
	1:10-2:02

Class Six: Riparian Plants

Feb 7, 2007	10:40-11:32
	12:15-1:07
	1:10-2:02

Field Trip to Winter Ponds Environmental Learning Center:

Restoration Planting

Feb. 21, 2007	AM
	PM
Feb. 23, 2007	PM

Class Seven: Animal Adaptations

March 7, 2007	10:40-11:32
	12:15-1:07
	1:10-2:02

Class Eight: Macroinvertebrates

March 21, 2007	10:40-11:32
	12:15-1:07
	1:10-2:02

Class Nine: Ethnobotany

April 4, 2007	10:40-11:32
	12:15-1:07
	1:10-2:02

Field Trip to Winter Ponds Environmental Learning Center:

Macroinvertebrates/ Riparian plants

April 17, 2007	AM
	PM
April 18, 2007	PM

Class Ten: Bird Migration

May 2, 2007	10:40-11:32
	12:15-1:07
	1:10-2:02

Class Eleven: Fish Biology/ Flip the Fish

May 16, 2007	10:40-11:32
	12:15-1:07
	1:10-2:02

Field Trip to Winter Ponds Environmental Learning Center:

Canoeing (possibility)

May 30 OR June 6	AM	(1.5 classes)
	PM	(1.5 classes)

This trip is tentative, pending funding of the Canoe the River event and pending date selection by the interested parties. Field trip day will like be either May 30 or June 6, pending the larger schedule for Canoe the River. Students will be canoeing a section of the River as a celebration of their year long study and restoration work in the watershed.

APPENDIX D

Level of Thinking Artifacts

Description of Tasks that Generated Quotes

Thinking Rubric

Description of Tasks that Generated Quotes

Three work samples:

- Overall points:
 - In their papers, students presented the analysis and conclusions in many different ways. In some instances, the students would nicely present both the findings and the interpretations as separate sections/paragraphs. More commonly, the sections were mixed together in one paragraph, and in still other instances, they only included one or the other, not both.
- Brine shrimp lab
 - The brine shrimp lab emerged mostly from the interests of the other teachers. In the text book, it was given as a simple activity to help students understand biotic and abiotic factors. It was decided to make it into a complete inquiry, but it was not an ideal inquiry. The question was predetermined (How much salinity do brine shrimp need to hatch and survive?), and was not a good question in many regards – it wasn't really answerable by the experiment we were doing, there wasn't a good way to quantitatively measure the hatching and survival rates (so students converted their qualitative observations into quantitative measurements/estimates), and the focus of the teachers was so heavily weighted on the writing at the end, the entire process took way too long (see the “brine shrimp saga” written as a reflection afterwards). Despite the flaws, we were able to introduce some important concepts and skills – the importance of accurate measurement, simple components of research design, and other unexpected things like the importance of dissolved oxygen...one can only hope that some of them made that connection with the work at Whitaker Ponds...
 - The quotes for scoring come from the questions that students wrote in their papers (although it was provided to the whole class, the wording students used varied widely – that may impact how they are scored). Quotes also came from the students hypotheses and analysis and conclusions.
- Heart rate lab – District “anchor” paper
 - This lab was also prescribed for the students, but this time from the district level. To ensure that students were being evaluated similarly across the district, the district has been implementing a series of “anchor” papers at every grade level from 6th through 10th (double check...), and in multiple disciplines. The science anchor papers have been modified from year-to-year, with the hope that they will eventually settle on well designed common assessments to use district-wide. The year of study, for sixth grade, the anchor assignment was involving human heart rate. It was fairly open-ended within that topic, but students were expected to generate papers graded by a rubric that was geared more towards writing than science.

- Our teaching team led student through a process of obtaining background information about the human heart and heart rate – what it is, what effects it, how it relates to diseases and other health issues, etc. We also taught student how to measure their heart rates by counting their pulse. The basic design was created by the teachers – how various exercises/activities affect heart rate? – but students in each class decided what exercises they wanted to do. For the actual lab, students first obtained their average resting heart rate, then went through a regimen of exercise for three different activities, measuring their heart rates at various time points along the exercise regime. For example, at the start of each exercise regime, students would first measure their resting heart rate (which could be compared to their average resting HR as a control and QA/QC check). After that, they would do their exercise for 3 minutes (e.g. jogging in place). At that point, they would measure their heart rate again. Then they would start resting, measuring their HR at one minute after stopping exercise and at four minutes after stopping. They collected their data and then used an online graphing program to help display and interpret their findings.
- In this work sample, the question was again teacher-generated for the most part. The main difference was the students were a bit more involved in the process of coming up with the question, and again, the each wrote it slightly differently. In addition to the questions, the quotes for analysis also include the students' hypotheses and analysis and conclusion sections of their final papers.
- Science Inquiry work sample
 - Although students had had a chance to work on an open-ended inquiry with their science fair project, this was the only work sample that students got to choose their topics and questions. Right before this was started, we also introduced the kids to the Vernier equipment, so most of them chose to do something involving Vernier equipment. In fact, the majority of projects involved the Vernier heart rate monitors (and something with sugar, chocolate and/or caffeine). There were a few instances where the questions students wanted to answer weren't feasible with the equipment or resources we had, but other than that, we allowed students to investigate whatever they chose.
 - Again, quotes for scoring include the students' questions, hypotheses, and analysis and conclusions from their final papers. The questions were student-generated, but the teachers gave final approval as indicated above.

Quiz Questions:

- Answers to select quiz questions (ones asking for higher-level responses)
 - Difference between autotrophs and heterotrophs
 - How does energy flow through ecosystems?
 - Using graphs, explain which river is best for salmon
 - Rating the water body; would it be same all the time? Why/why not?

Other sources of student thinking

- Outdoor School workbook question about why some rivers or streams flow more slowly than others
- Science fair components when available...since they produced boards, I don't have them for many students. In some cases, the students left copies laying around and I collected them for files.

Journal prompts and Quick-Writes:

- Journal prompts and quick-writes about what was learned, what is confusing, what you still want to know; and
- Any questions you have
- How seeds travel
- End of year quick write about what was learned, what was most interesting, and why learning about our home on earth is important.

Hypotheses from labs:

- Soil jars
- Peas
- Bacteria
- Density (this one also included their results and conclusions)

Thinking Rubric

Evaluation of Thinking

Bin 1 – Low level of cognitive complexity

- For work sample questions, hypotheses and analysis & conclusions
 - Yes/no questions; not answerable; little depth; may ask what is commonly known
 - Predictions mostly state the obvious/what is already commonly known (in most cases, any prediction at all would mean the score was at least a 2)
 - Analysis non-existent or quite simple
 - Yes/no answers to questions on assignment sheet without any explanation or reasoning
 - No improvements to experimental design
- For responses to quiz questions and journal/quick-write prompts
 - Simple responses with no depth, connections or insights
 - Recall of information without any “so what” or connections/application/transfer

Bin 2 – Low to moderate-level of cognitive complexity

- For work sample questions, hypotheses and analysis & conclusions
 - How/what/why questions – little or no depth/insight, doesn’t go beyond what is already commonly known...might be worded as a yes/no question, but the implication is a how/what/why question; not as open to investigation
 - Question may not be answerable
 - Predictions that may include why the students thinks it (probably not), but with little depth or connections; often state the obvious/what is commonly known
 - Analysis may state results, but without interpretation and/or limited explanation of what it means
 - Any suggested improvements to experimental design are superficial or not well-developed/explained
- For responses to quiz questions and journal/quick-write prompts
 - Simple responses, connections are not necessarily logical or sensical
 - Recalled information that includes any shred of transfer/application/connections

Bin 3 – Moderate to High-level of cognitive complexity

- For work sample questions, hypotheses and analysis & conclusions
 - How/what/why questions with more depth and insight; some interesting twist or insight expressed or inquired
 - Question may be answerable (maybe not); opens door for stronger investigation/experimental design
 - Predictions include why the students thinks it with more depth, incorporates and/or synthesizes information and past knowledge

- Analysis – states results with some interpretations of what it means – connections, transfer, application and or insights
- Suggested improvements to experimental design are more meaningful, show reasonable understanding of errors and/or limitations
- For responses to quiz questions and journal/quick-write prompts
 - Responses include connections that may not be expressed perfectly (language differences?), but demonstrate deeper thinking

Bin 4 – High-level of cognitive complexity

- For work sample questions, hypotheses and analysis & conclusions
 - How/what/why questions express deeper thinking of topic; question arising from synthesis or transfer of other knowledge/understanding
 - Question answerable
 - Predictions show depth, explain reasoning/thinking, synthesizes background knowledge and understanding, makes connections/transfer
 - Analysis – results presented with interpretations, insights, connections and/or transfers; more depth
 - Improvements to experimental design show insight and understanding of research, errors and/or limitations
- For responses to quiz questions and journal/quick-write prompts
 - Responses express own/unique thinking; more depth/insight; synthesis of learning, transfer and/or connections; explains why/how the student arrived at this answer/thought

Factors to pay attention to:

- Scientific language
- Everyday language that expresses understanding of some scientific concept or process
- Example or implication of making connections to...other discipline, other activity, everyday life...
- Making predictions; pay attention to when students included explanations of why they made that prediction
- Evidence of synthesis – are they tying other concepts, actions, processes together?
- Concepts learned/understood
- Insights made – could be connections, could just be an interesting point that isn't commonly made
- Misconceptions, misunderstandings, misteaching, misinterpretation, misuse...
- Make notes when these things are observed

APPENDIX E

Student Focus Group Protocol

Student Focus Group Questions

Semi-Structured Interview Protocol

1. What was your favorite activity or activities in science?
2. What about the River School activities? What were your favorites?
3. What did you learn this year? What do you think will really stick with you next year and beyond?
4. Thinking about River School, what did you learn from those experiences – the classroom visits from Ms. Felice and the field trips?
5. What was the most confusing thing you learned, or what you didn't like learning about this year?
6. What about the River School activities?
7. Do you the way you think about where you live changed during the course of the year? How so?
8. How has River School contributed to these changes?
9. How do you feel you best learn science?
10. What do you think you want to do in high school and beyond?

APPENDIX F

Themes from Phase One of Grounded Theory Analysis

Themes, categories and subcategories that emerged from the first phase of grounded theory analysis – bullets in bold could be categorized under more than one heading.

Theme 1: Science learning and teaching

- **Learning and understanding**
 - **Social constructivism**
 - **Individual vs. group**
 - **Own ideas vs. shared ideas**
 - **Collaborative work/ sharing responsibility**
 - Use of scaffolding, teacher support
 - **Interest/engagement**
 - Desire to do well...is this the same as desire to learn?
 - **Student-centered**
 - Data analysis
 - **Confronting conceptual change**
 - **Hands-on activities**
 - **Problem-solving**
- **Misconceptions**
 - **Expressed**
 - **Not yet uncovered**
 - **How do we tap/discover?**
 - **Are they common/similar among students?**
- **Engagement**
 - **Hands-on**
 - Student-generated topics
 - **Tapping into personal relevance/interest/experience**
- **Social interactions in group work**
 - **Student groups with different ideas/hypotheses**
 - **Navigating disagreement**
 - **Who's "right"...how is that negotiated?**
 - **Level of comfort or discomfort with disagreement**
- **Student Frustration**
 - With content
 - With inquiry process
 - **With writing**
 - **With social dynamics**
- **Teaching**
 - How much do teachers need to lead vs. students discovering connections?
 - Teaching and/or reinforcing misconceptions
 - **Teacher knowledge and skills**
- **Technology – trouble shooting in 50 minutes**

Theme 2: Adolescents

- **Self-concept and student views**
 - **Identity acquisition from past schooling/institutional labeling**
 - Self-awareness
 - Views of school/ identity acquisition from school/community
 - **Social mobility**
 - **Ability to change**
 - **Predetermined destiny**
 - **Control over their destiny/future**
 - **Personal connections → relate to engagement and self-image/concept**
 - Self-awareness / self-criticism
- **Concrete vs. abstract thinking**
 - Student wisdom/ insight
 - **Curiosities**
 - **What shapes them?**
 - **How do they connect to personal experience?**
 - **Personal connections**
 - **How to access?**
 - **How to draw on students' assets/capital?**
 - **How does this relate to self-regulation?**
 - Initiative
- Middle school dynamics and characteristics
 - Social aspects of middle school
 - Importance of friends/getting along
 - **Working with friends vs. working with people they don't want to**
 - Striving for approval/validation
 - From teachers
 - from peers
 - Caring/ interested adults
 - Social concerns
 - Popularity
 - Esteem
 - Tension between getting along and "problems"
 - **"Issues"**
 - **Student organization/work management**
 - Temperament
 - "Calls for help" / search/quest for connection (draw on 40 Assets)
 - **Confusion/frustration in science**
 - **Trust**
 - **Resistance**

- **Conflict**
- **Classroom antics / behavior challenges**
 - **Behavior management strategies**
- **Exceptions to every rule/ each student has unique story**

Theme 3: Cultural and linguistic aspects

- **Cultural & linguistic expressions/interactions**
 - **Verbal vs. written**
 - **Scientific language vs. everyday language**
 - **Scientific writing vs. more descriptive/contextualized styles**
- **Challenges with writing**
 - In general
 - **Expressing scientific ideas**
- **Voice for writing – storytelling/narrative**
 - **Using evidence/data in reports**
- **Talking things out vs. writing**
- **Language usage to describe natural phenomena**
 - Use of metaphors – familiar descriptors
 - Ways of describing complex phenomena in words
- **Questioning and thinking**
- **Visual / artistic learners**
 - **Way to express ideas/concepts**
 - **Engagement strategy**
- **How do students make connections?**
 - **Explicit**
 - **Implicit**
- **Sense-making**
- **World views**
- **Connections**
 - With the Earth
 - To nature
 - Between subjects

To personal lives