Science Education at Riverside Middle School

A Case Study

by

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ABSTRACT

For more than thirty years the gender gap in science and related careers has been a key concern of researchers, teachers, professional organizations, and policy makers. Despite indicators of progress for women and girls on some measures of achievement, course enrollment patterns, and employment, fewer women than men pursue college degrees and careers in science, technology, engineering, and mathematics. According to the results of national assessments, the gender gap in science achievement begins to be evident in the middle school years. Gender and school science achievement involve a complex set of factors associated with schools and child/family systems that may include school leadership, institutional practices, curriculum content, teacher training programs, teacher expectations, student interests, parental involvement, and cultural values.

This ethnographic case study was designed to explore the context for science education reform and the participation of middle school girls in their science classrooms. The study analyzed and compared teaching strategies and female student engagement in sixth, seventh, and eighth grade science classrooms. The setting was a middle school situated in a district that was well-known for its achievement in reading, math, and technology.

Findings from the study indicated that while classroom instruction was predominantly organized around traditional school science, the girls were more disciplined and outperformed the boys. The size of the classrooms, time to prepare for hands-on activities, and obtaining resources were identified as barriers to teaching science in ways that aligned with recent national science reform initiatives. Parents who participated in the study were very supportive of their daughters' academic progress and career goals. A few of the parents suggested that the school's science program include more hands-on activities; instruction designed for the advanced learner; and information related to future careers. Overall the teachers and students perceived their science program to be gender fair. Eighth grade participants who had career goals related to science and engineering, indicated that their science instruction did not provide the rigor they needed for critical skills in high school advanced placement courses. Recommendations include the need for professional development on inquiry-based science, equitable student achievement, and diverse perspectives in science education.

This project is dedicated in loving memory

of my brother Ernie Mayes for his legacy of higher education;

the memory of my father, James K. Pickens, Sr.;

and the memory of my brother-in-law, William (Bill) Charles Ingram.

This is also for my mother Bettie Mae Pickens.

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INTRODUCTION

Gender inequity in school science achievement involves a complex set of factors that include: school leadership, institutional practices, the skills of teachers and counselors, curriculum content, teachers' expectations, physical facilities, financial and material resources, public policies, community resources, teacher training programs, students' interests, parental involvement, and cultural values (Barton, 1998; Barton, 2004; Kawagley, 1998; Kesidou & Roseman, 2002; Kijanka, 2009; Rorrer, Skria, & Scheurich, 2008; Scantlebury & Baker, 2007). The National Assessment of Educational Progress (NAEP) and other national and international assessments are often used as indicators to show that males consistently outperform females in science achievement (College Board, 2010; NAEP, 2000, 2005, 2009; Trends in International Mathematics and Science Study [TIMSS], 2007). The average (NAEP) scores reported for eighth grade students between 1996 and 2005 indicated that male students scored slightly higher than female students in science. Likewise, the overall trend in high school scores from the NAEP (2005) and SAT (2010) show that male students scored consistently higher than female students in both science and math.

Eisenhart and Finkel (1998) argued that girls and boys enter elementary school with equal interests in science, but experience science very differently. In middle school, for example, Sadker and Sadker (1994) reported that boys frequently used scientific instruments, read more science-related books, and received higher grades on science assignments. Further, boys received more teacher feedback and interactions with the teacher that challenged them to finish their school activities. More recently, Duckworth and Seligman (2006) completed a study on overall course grades and achievement test scores on eighth grade girls from an urban magnet school located in the northeastern part of the U.S. The authors found that the eighth grade girls were more self-disciplined and earned higher grades than boys in all of their major school subjects, but scored lower on some achievement tests and IQ tests (p. 198). Despite the differences in these findings, girls and women continue to be underrepresented in some science, technology, engineering and mathematics (STEM) courses and careers (American Association of University Women [AAUW], 2010). The contrasting findings also suggest a need to explore the context for girls' achievement as well as other factors that may improve or inhibit their performance.

One of the strategic goals of the National Science Foundation (NSF) is to increase the participation of women and girls in science, technology, engineering, and mathematics (STEM). Since 1982 the NSF has submitted reports to the U.S. Congress on the participation of women, minorities, and persons with disabilities in science and engineering (NSF, 2000). The Program for Gender Equity (PGE) at NSF began in 1993 to improve the participation of groups underrepresented in STEM fields. Through these efforts NSF funds many K-16 programs with university partnerships that aim to recruit girls, women, minorities, and persons with disabilities into advanced STEM courses and careers (Committee on Equal Opportunities in Science and Engineering, 2009; NSF, 2000, 2001). Science educators and community stakeholders (i.e. colleges, universities, school administrators, parents, students, community leaders, teachers, counselors, and policymakers) will play critical roles in support of equity in science education reform.

Background

The No Child Left Behind Act of 2001 (NCLB) increased educational requirements for states and school districts. Before 2001 science was not a requirement in national or state education laws. In 2006 content standards for science were required as part of the federal and state accountability systems. Annual progress for all students and subgroups defined by gender, socioeconomic status, ethnicity, language proficiency, and disability are measured for academic improvement (Betebenner, 2009; Linn, Baker & Betebenner, 2002). Science content standards and assessments follow the same requirements used in the past for reading and mathematics assessments that are linked to the standards-based education reform movement.

Buxton (2010) argued that one of the stated goals of the No Child Left Behind Act (2001) was to reduce achievement gaps, but little has been done to reduce gaps in science achievement across racial and ethnic subgroups. White males continue to outperform African Americans and Hispanic students across all areas assessed in science. The same is true for female students. Average science scores on the NAEP (2009) indicated that scores for male students were higher in grades four, eight, and twelve. In middle school, only 18% of female eighth graders in the southwestern state where this study was conducted demonstrated science proficiency on the NAEP science assessment compared to 26% of male students. In addition, 49% of the eighth grade female students scored below basic levels in science compared to 44% of the male students.

According to the data from the NAEP, 2005 the gender gap in U. S. elementary science classrooms is narrowing. However, of the 44 states participating in the NAEP (2005), all reported that boys outperformed girls in grade 12 science education achievement. This is not a new phenomenon. Lynch (2000) described a similar pattern from 1977 through 1992 evidenced in the NAEP scores. Lynch (2000) also reported gaps in grade 12 science course enrollment patterns. For example, more female students were enrolled in biology and chemistry, while male students were enrolled in more physics courses. Lynch (2000) noted that a key influence on the gender gap in science achievement was not related to course taking patterns, but the students' attitude toward science.

> Females like science less, see it as less important to their future, and are less confident about their abilities in it even when their achievements in it are the same as the males. Only 2.8% of female high school students are likely to aspire to careers in science, math, and engineering, compared to 10% of their male peers. (p. 26)

The NAEP (2005) trend for completing courses in science indicated that compared to male students, female students improved their course taking patterns in biology and chemistry. However, the enrollment rates of male students in biology, chemistry, and physics continued to increase during this same period.

The gender gap in STEM is also reflected in college degree attainment, careers, and salaries. The Association of University Professors ([AUP], 2004) reported that on average, fewer women received bachelor, master, and doctoral degrees in STEM fields like computer science. In addition, only 19% of the college women enrolled in STEM received bachelors' degrees. Twenty percent of the graduates were women who received degrees in engineering and 35 % of the graduates were women who received degrees in the physical sciences. Beyond the course taking patterns, women professors ranked lowest in the same fields of specialization. The AUP (2004) also reported that only 18% of the professors in computer science were women; 10 % of the engineering professors were women; and 15% of the professors in the physical sciences were women.

Similar trends are evident when women's salaries are compared to men's. For example, from 1993 to 2003, the annual median salary of women in the STEM labor force was between $40,000 and $53,000 compared to men who earned between $50,000 and $70,000 respectively (NSF, 2008). The breadth of the gender gap in science education suggests that it would be important to examine the nature of science education in the middle school grades, when girls begin to make decisions about pathways to science and related careers (Barton, 2008).

The purpose of this qualitative ethnographic study was to better understand the complex culture of science education for middle school girls. The analysis included the girls' perspectives on their experiences in science and the classroom observations included an analysis of the overall school science curriculum.

Theoretical Framework

Middle school is widely considered a key stage in the lives of adolescents who make critical decisions regarding their role in school and society (National Middle School Association, 2006). In middle school, many students will decide their leisure, course-taking, and career interests based on factors and experiences that make up their social realities. Several studies have indicated that middle school is a particularly critical stage for influencing girls' interests and aptitude in science achievement (AAUW, 1996; Clewell & Ginorio, 1996). Brotman and Moore (2008) argued that few researchers have considered questions on gender and science related to school cultures and the administrators' perspectives on girls and their science achievement. This qualitative ethnographic research study draws on a view of school culture and context as a system of interrelated parts as the overarching frame for the analysis.

Middle school science education and issues associated with gender are viewed as interdependent systems. Pianta and Walsh (1996) described systems as "abstract units" that function at superordinate and subordinate levels within schools, classrooms, peer groups, families, and other social environments (p. 65). For example, a school operates within dynamic relationships of key people and institutions. Individual schools include different levels of systems such as the administrators, counselors, teachers, other personnel, students, and the community. In most U. S. communities, a school is a subgroup that is part of a larger system such as a school district. The school district is governed by a local community of leaders (a school board) who are elected by their peers or appointed by the state or county superintendent of schools. State departments of education regulate governing boards. School districts that receive federal funds must also follow rules and procedures set by the federal government. Schools are, therefore, "embedded within various cultural and subcultural contexts . . . [which] can influence [multiple] relationships between the child, family, and school" (p. 69).

The Contextual Systems Model (CSM) was designed by Pianta and Walsh (1996) to focus on the relationships between two major systems: (a) the child/family system and (b) the school system. Their model helps to locate factors identified with effective or ineffective schools and classrooms. In this case, interactions within middle schools are bound by local, state, and national science education policies. The extent of a student's science education experiences is the result of interactions among and between subordinate and super-ordinate systems. Each of these cultural systems conforms to patterns and rules that regulate the behavior of individuals and other social groups in different environments, constructed over time. It is the quality of these interactions that contribute to the student's performance (pp. 79-81). Science achievement occurs within a larger support system, which includes the community, family, classroom, school, and the school district's science curriculum team. The CSM will be used as a lens to understand science education in a middle school system and the factors that may support or constrain achievement for girls.

Another aspect of this qualitative ethnographic study includes observations of a representative science unit in grades six, seven, and eight at Riverside Middle School, a typical middle school in a district that is well known for its achievement in reading, math, and technology. Each instructor's teaching strategies during the unit was analyzed using the school science traditions theory.

Zacharia and Barton (2004) created a continuum to characterize three main traditions in middle school science: (a) Traditional School Science (TSS), (b) Progressive School Science (PSS), and (c) Critical School Science (CSS). The three traditions are derived from some of the major reform efforts in the history of science education used in the United States. Traditional School Science (TSS) was designed during the 1960's. TSS supported a "positivist worldview" (p. 200). Science in this curriculum is viewed as objective and designed for controlled environments. Progressive School Science (PSS) was created in the 1990s to include science education reform movements. This period emphasized a "constructivist orientation" (p. 201) that combined students' knowledge and questions with understandings and practices used in the laboratory. Critical School Science (CSS) was defined by the "feminists, multicultural, and critical perspectives" (p. 201) of teaching in the latter part of the twentieth century. CSS involves a fluid course of study that embraces diversity and connects science to the everyday lives of children. CSS is bound by context and the local community needs and is always based on the lived experiences of its participants. Each type of science has a different assumption about the "nature of science; ways of knowing and evaluating science; school, science, and society; science as a school subject; school science and student relationships; and goals and purpose of science education" (pp. 203-204). Zacharia and Barton (2004) noted that the categories are not "completely distinct from each other" (p. 200). Instead, there is some overlap between the categories. For example, “Much of the science-technology-society curricular work developed in the 1980s and 1990s fits on a continuum that sits between PSS and CSS” (pp. 201-202).

These categories will be used as a lens to understand the science instructional strategies used within the three classrooms observed in this study. Both the child-family system and the individual school system will be explored by including perspectives from students, their parents, teachers, counselor, and the principal. The research questions were:

1. What type of science best characterizes Riverside Middle School’s science program?
2. How did the teachers perceive their science instruction?
3. How did the middle school girls perceive their science instruction and learning?
4. How did the parents perceive science instruction and learning for their daughters?

The strategy of inquiry was ethnographic. I conducted a case study of a middle school in the southwestern United States. I selected the school district because of the consistent participation of teachers, counselors, and students in the Women in Science and Engineering (WISE) Investments program at a local university. The school principal selected the science teachers to participate in the study. The teachers chose the classrooms and units for observation. I observed and documented the science classroom interactions of 19 female students and three teachers from grades six, seven, and eight and conducted interviews with the principal, counselor, and teachers to assess the school's efforts to ensure science equity for girls. In addition, I held focus groups with the parents and the student participants. In the latter, I wanted to explore the parents' support and resources for supporting their daughters' interests in science. Interviews were conducted to answer the following questions: (1) Were there conscious (explicit) efforts to support gender equity in science achievement at this middle school? If so, what were these efforts? (2) What were the perceptions of teachers, parents, and the administrators for gender equity? (3) What role, if any, did parents and teachers play in supporting gender equity at this middle school?

Each female student participant was asked to respond to questions in a journal that prompted them to describe and assess their science lessons and classroom instruction to answer the additional questions: (a) What were the girls' perspectives on participation and achievement in their science classroom? (b) What were the girls' levels of confidence and interests in science? (c) Did the science curriculum encourage or discourage girls' participation? (d) What type of activities inspired girls during their science instruction?

Significance

Research studies indicate that women and girls remain a seriously underrepresented population in advanced science classrooms and in science-related careers (AAUW, 2010; Hyde & Gess-Newsome, 2000; Kahle, 1996; NSF, 2000). Women and girls' disproportionate representation in science suggests that there continues to be a need to promote and sustain their achievement in science education reform as early as middle school. This study provides:

1. A knowledge base for understanding science instruction for middle school girls.
2. A better understanding of how middle school girls perceive and describe their science education.
3. An understanding of how classroom instruction aligns with the current National Science Education Standards (NSES) that call for equity and excellence.

Summary

The purpose of this qualitative case study was to explore how middle school science was taught in the three classrooms and how girls in the participating classrooms experienced science education. In this chapter I introduced a brief background on national assessment data in science performance scores which suggest a persistent gender gap in science achievement. I also introduced the theoretical frameworks of the study (a) Pianta and Walsh’s (1996) Contextual Systems Model theory and (b) Zacharia and Barton’s (2004) School Science Traditions. The Contextual Systems Model helps us understand the middle school as a system of interrelated parts that work to support or limit the performance of girls in science. Zacharia and Barton’s theory will help me to more specifically analyze the science curriculum at Riverside Middle School as a way of better understanding middle school girls’ experiences in their science classes and their attitudes about science. The next chapter will review the literature on the history of science education reform and issues associated with equity in science education.

Chapter 2

REVIEW OF THE LITERATURE

Scientific literacy has been one of the most important features in science education for more than a century (DeBoer, 1991). According to the results of international and national assessments such as the Third International Mathematics and Science Study (TIMSS) and the National Assessment of Educational Progress (NAEP), the United States has made disproportionate progress in science education among subgroups. As such, the National Science Education Standards ([NSES], 1996) were created to promote scientific literacy for *all* students. The national goals were designed to ensure that *all* students achieve the "scientific knowledge, skills, and habits of mind needed to make personal decisions; engage in science-technology-society debates; and be productive members of our global society" (Bianchini, et al., 2002, p. 419). Likewise, researchers in the field of science education (Baker & Piburn, 1997; Barton, 1998; Brotman & Moore, 2008; DeBoer, 1991, 2000; Eisenhart, 1998; Kahle, 2007; Lynch, 2000; Scantlebury & Baker, 2007) have focused on the complexities of making scientific literacy a reality for *all* students in the twenty-first century. In order to understand science education, this review begins with a brief history of science education and efforts at reform.

A History of Science Education Reform

According to DeBoer (2000) science education was introduced as a course study in public schools in the nineteenth century at the request of scientists. Prominent educators felt that an insufficient amount of interest and time was devoted to science in public school curricula. It was also argued that the entire educational system did not adequately support science instruction and failed to recognize science as an important course. One of the proposed goals of science teaching was to “develop mental abilities and to empower persons for useful action in their lives” (DeBoer, 1991, p. 30). Another goal was to encourage students to “study the physical world with objects and instruments using the inductive process through careful observation, sensory, and the ability to reason” (p. 31). Yet these early science educators determined that the goals for science education were interpreted differently by classroom teachers. Classroom observations conducted in elementary and secondary schools noted that science was taught from a textbook similar to a course in language arts. For example one classroom observation described a science lesson on the human body in an elementary school classroom.

> I imagined that there might be a skeleton in that school, or a manikin, or a model of the brain, stomach, lungs, eye, ear, head, or arm, and that the children might be shown some of these beautiful organs. But no; there was nothing of the sort in the school-house, and there never had been. . . [I]nstruction, as developed through those books, --unless lightened by the personality of the teacher, --is dullness, a complete lack of human interest . . . (Eliot, 1898, p. 190 cited in DeBoer, 1991, pp. 32-33)

Leading educators rated the quality of science education as inadequate.

In the twentieth century the goal of science education was “to provide a broad understanding of the natural world and the way it affected people’s personal and social lives" (DeBoer, 2000, p. 584). To improve public support for science as a course of study, science was promoted by scientists because of its contributions to modern life. But, shortly after World War II the public support of science education began to diminish with the reality that developments in science and technology had the "potential to destroy society" (p.584). To maintain U.S. economic and military status, scientists and military personnel encouraged science education as an important resource Years later, following the launch of Sputnik in 1957 by the Soviet Union, the government dramatically increased support for science teaching and science education with a focus on the "logical structure of disciplines [biology, physics, chemistry] and on the processes of science" (DeBoer, 1991, p. 147).

Kahle (2007) identified three waves of large scale systemic reform in science education beginning with the launch of Sputnik and the space age. The first wave of school science reform occurred between 1957 and 1980. This reform movement focused on improving textbooks and teaching, along with federal support to develop curricula and teacher training programs. Curricula were created with support from the National Science Foundation (NSF) to include "projects in the earth sciences [time, space, and matter], physical sciences, engineering, and elementary science" (DeBoer, 1991, p. 157).

During the second wave of science education reform from the 1980s to 1990s, science educators called for "the need to improve scientific literacy of all citizens in the new technological age" (Kahle, 2007, p. 912). The Education for Economic Security Act was passed in 1984 "to promote the teaching of mathematics, science, and foreign language" (p. 922). Some states began to change their entire school systems for the purpose of accountability by using high-stakes tests to ensure students graduated from high school and college with enough competence and courses in science and math to advance the quality of life in the U.S.

The third wave of reform began in the 1990s with the National Science Foundation's (NSF) Statewide Systemic Initiative (SSI) program. The goal of the SSI was to improve science and mathematics through standards-based systemic reform. This reform became a national priority that was directed toward classrooms, students, and teachers. The themes used during this period were "excellence and equity" to improve overall student achievement and close the gap between students who were traditionally underserved (Kahle, 2007, p. 912). To reach a large population of students, many states focused on improving science and math achievement gaps at the elementary and middle school levels. However, the term "equity" was defined differently by states depending on how states defined underserved subgroups. For example, some states focused on science curriculum to address issues related to multicultural education. Other states emphasized curricula for students from households with low-incomes or curricula designed to improve achievement for female students. Several states also "took measures to expand the pool of effective leaders" (p. 931) in their science educational systems at the state and regional levels. The SSI program gained momentum with the development of science educational standards.

The Governing Board of the National Research Council ([NRC], the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine) approved the National Science Education Standards (1996) (NSES). The NSES were created as a guide for improving science teaching and learning for *all* students enrolled in elementary and secondary schools.

> The *Standards* assume the inclusion of all students in challenging learning opportunities . . . [and] emphatically reject any situation in science education where some people . . . are discouraged from pursuing science and excluded from opportunities to learn science. (NSES, 1996, p. 20)

Improvements to science education were promoted as one part of the systemic education reform movement. Science education was viewed

> as a subsystem with both shared and unique components [to] include students and teachers; schools with principals, superintendents, and school boards; teacher education programs in colleges and universities; [curriculum frameworks] textbooks and textbook publishers; communities of parents and of students; scientists and engineers; science museums; business and industry; and legislators. (NSES, 1996, p. 21)

Baker and Piburn (1997) argued that “the most important lesson learned from . . . [the] history [of science education] is that the curriculum is not a neutral entity that exists beyond the constraints of society, [science education] is a tool used by society to achieve its goals” (p. 7).

Other NSF initiatives to improve equity in math and science have included the Urban Systemic Initiatives (USIs) and the Rural Systemic Initiatives (RSIs) programs (Kim & Crasco, 2006, p. 19). The NSF provided grants to urban and rural school districts to increase achievement in science, math, and technology for urban and rural underrepresented minority students living in poverty (p. 20). The funding was directed toward "comprehensive systemic changes at all levels of the educational enterprise, including the school district and school building, and in the relationships between schools and associated universities, industry, and other societal partners" (p. 20). Cooperative agreements were signed between the federal government and state school systems to transform standards, curricula, assessment, professional development, partnerships, and the merging or uniting of fiscal and intellectual resources.

Kim and Crasco (2006) assessed the research and evaluation outcomes regarding best policies and practices in science education reform. The researchers focused on student achievement and equity from 21 USI sites. Findings from the reports indicated the following:

1. Detracking students increased enrollment in higher level courses in math and science.
2. Significant enrollment gains were noted in advanced level math and science courses from traditionally underrepresented minority students.
3. Substantial gains were reported in assessment results along with reduced achievement gaps among racial and ethnic groups. Eighth-grade science assessment test results also indicated significant improvement.

4. There was an increase in the number of students taking college entrance exams (pp. 25-26).

The foundation for the success as documented at USI sites was a "belief system" that held high expectations for all students (Kim & Crasco, 2006, p.34). Other key support structures involved implementing policies for "high-quality learning and teaching, including professional development and student support" for equity in science, technology, and math achievement. Teachers, administrators, and staff worked in local programs to provide services to all students who were in need of resources to improve their performance (pp. 34-35). At successful USI sites there was a continuous focus on professional development to create support for teachers on standards, curricula, and research for best practices. In addition, efforts to promote student achievement involved support systems for students that included tutoring and related activities. These broad-based support systems were strengthened through sustained relationships with school and district leadership and management; business partners, higher education, parents, and local communities.

While some progress has been made in closing achievement gaps in science, other studies indicated that more than ten years following the NSES, women, girls, and other subgroups continue to be disproportionately underrepresented in achievement and careers related to science and science education (American Association of University Women (AAUW), 2010; The National Assessment of Educational Progress (NAEP), 2005, 2009; Scantlebury & Baker, 2007). Indicators for K12 science achievement include scores from the

NAEP. The NAEP-- " the best assessment system available for a national overview of the state of K12 science" (Lynch, 2000, p. 22).

Overall average science scores across all participating states in 2009 were lower for female students in grades four, eight, and twelve. Demographically, white students continued to outperform black and Hispanic students. Beyond K12 science assessments, the AAUW (2010) reported that "social and environmental factors contribute to the underrepresentation of women in science and engineering" achievement, program opportunities, and careers. (p. 14). The next section will focus on the research related to the nature of school science as well as student attitudes and gender differences within the current reform science education movement.

The Nature of Science in Schools

Duschl, Schweingruber, and Schouse (2007) argued, "Before one can discuss the teaching and learning of science, consensus is needed about what science is" (p. 26). During the third wave of reform, Collette and Chiappetta (1994) combined the perspectives of a scientist, a philosopher, and a nonprofessional to argue for a conceptual understanding of science "as a human enterprise" for K12 educators (p. 30). Collette and Chiappetta (1994) noted that "[s]cience should be viewed as a way of thinking in the pursuit of understanding nature; as a way of investigating claims about phenomena; and as a body of knowledge that has resulted from inquiry" (pp. 30-31).

Consistent with the above perspective, Duschl, Schweingruber and Schouse (2007) contended that "science is both a body of knowledge that represents a current understanding of natural systems and the process whereby that body of knowledge has been established and is being continually extended, refined, and revised" (p. 26). Teaching and learning science in the K-8 curriculum from this perspective includes engaging students in science as a meaningful and productive practice in which students

1. know, use, and interpret scientific explanations of the natural world;
2. generate and evaluate scientific evidence and explanations;
3. understand the nature and development of scientific knowledge; and
4. participate productively in scientific practices and discourse.

   (Committee on Science Learning, Kindergarten through Eighth Grade, 2007, p. 2).

In contrast, Zachariah and Barton (2004) argued that "a common, objective science does not exist" (p. 200). These authors developed a continuum of science teaching traditions that is linked to the history of reforms in science education. According to Zacharia and Barton (2004) there are three school science traditions (a) Traditional School Science (TSS), (b) Progressive School Science (PSS), and (c) Critical School Science (CSS). The school science traditions identified by Zacharia and Barton overlap to some degree with Kahle's (2007) three waves of systemic reform described earlier in this chapter. For example, TSS is aligned to the first wave of science education reform and PSS is more aligned to Kahle's third wave of reform. However, Kahle does not address the more critical issues raised by CSS.

Within the TSS category "[t]he nature of science is presented from a positivist world view—scientific knowledge is an objective representation of how the world works" (p. 203). TSS is typically presented as a study of isolated facts "with little regard as to how scientific information is generated" (Collette and Chiappetta, 1994, p. 22). The subject matter in TSS is teacher-centered and highly structured. TSS "ignores the relationship between science and culture" (Zacharia & Barton, 2004, p. 201). Scientific information, as a body of knowledge, is presented to students who are regarded as "passive receivers" (p. 201). Teacher lectures and note-taking, along with worksheets and textbooks are dominant in the TSS curriculum. Children experience science through memory at the recall level of reasoning. In TSS "[s]tudent interests or the pedagogical need to relate scientific knowledge to the experiential world of the student are secondary to the primacy of content" (p.201).

PSS is rooted in the philosophy of progressivism. Progressive education "is grounded in the scientific method of inductive reasoning . . . [I]t encourages the learner to seek out those processes that work and to do those things that best achieve desirable ends" (Webb, Metha, & Jordan, 1996, p. 212). PSS is conceived as "an orientation to the school science that has emerged . . . from the recent reform initiatives in science education" (Zacharia & Barton, 2004, p. 201). PSS is a child-centered approach to learning. From a historical perspective in the 1960s, PSS was designed to make science meaningful and relevant, emphasizing the students' "everyday activities and interests [as well as] preparing them for life in society" (DeBoer, 1991, p. 141). PSS is also based on "constructivist learning," by using prior knowledge students think about the previous concepts they have learned as they integrate new ideas to increase their understanding of scientific knowledge, process skills, and products (Baker & Piburn, 1997; Harcombe, 2001; Martin & Hand, 2009; Zacharia & Barton, 2004).

Within the PSS framework, the use of science labs is strongly emphasized and students are required to be active participants in their learning. Students work collaboratively to learn science concepts and principles through experiences with a variety of materials and tools used in problem solving. The materials and tools are used to expose students to questions, predictions, observations, how to organize data, define operations, explain patterns, and communicate solutions by using evidence to make their claims (Collette, 1994; Martin & Hand, 2007).

CSS positions school science within a social, political, cultural, and historical framework. Zacharia and Barton (2004) proposed that CSS is taught from the perspectives of "critical, feminist, and multicultural school science" (p. 201). From a critical perspective, science cannot be separated from society because the nature of science reflects values in language, culture, and human experiences (Barnhardt, 2007; Eisenhart & Finkel, 1998; Kawagley, Norris-Tull, D., & Norris-Tull, R., 1998; Lemke, 2001; Lim & Barton, 2006; Luykx, Lee, & Edwards, 2007; Lynch 2000; Semken, 2005; Williams & Lemons-Smith, 2009). One example of a CSS-oriented science curriculum includes lessons on the culture and experiences of American Indians and Native Alaskan students with the Earth, a relationship in which "spirituality comprises an important aspect of [their] learning and lifestyle" (Lynch, 2000, p. 120). As a social practice, CSS challenges students “to construct science out of their own questions and experiences” (Barton, 1998, p. 16). Students experience science as active participants in solving and assessing social problems associated with the needs of their local communities.

Student Attitudes and Gender Differences Toward School Science

Researchers have used a variety of methods to explore student attitudes towards school science (Brotman & Moore, 2008; Scantlebury & Baker, 2007). Jones, Howe, & Rua (2000) surveyed gender differences in 437 sixth grade students’ attitudes, interests, and experiences in science. Their study was conducted in rural, urban, and suburban communities in five schools located in the southeastern part United States. The survey instrument was designed by an international team of science educators and piloted in different countries to emphasize issues of culture, gender, and science education.

Jones et al.’s (2000), findings indicated that girls perceived science as difficult, while boys perceived science as easy to understand, better suited for boys, dangerous and destructive, and causing problems in society. The survey also assessed gender differences in students’ learning interests. For example female students were interested in working with animals, weather patterns, and issues related to health. Male students reported learning interests related to atomic bombs, cars, computers, dinosaurs, and the latest technologies. In addition, the survey asked students to respond to the out of school activities they participated in that were science-related. Girls reported engaging in activities related to cooking and natural phenomena such as watching a bird make a nest, astronomy, and working with plants. Male students reported participating in out-of-school science-related experiences in topics related to electricity, using air guns, microscopes, pulleys, and firewood. Overall, female students reported more interests in biology while male students reported more interests and experiences in the physical sciences. Jones, et al.'s (2000) findings highlighted the importance of exposing female students to early experiences in the physical sciences to improve their interests, achievement, and future opportunities related to STEM careers.

As described above, Zacharia and Barton (2004) identified three school science traditions which they used as frameworks for analyzing urban middle students' attitudes toward the content and context used in activities specifically associated with PSS and CSS. Zacharia and Barton developed and administered an attitudinal survey to 170 sixth grade students that asked the participants to evaluate scenarios featuring "science in action" from each of the two school science perspectives (p. 204). The students were enrolled in three separate middle schools located in a large urban school system in New York. Each school emphasized one of the following areas: the arts, computer science, or the natural sciences. The findings indicated that all students had an "overwhelmingly positive" attitude toward the CSS activities (p. 217).

Disaggregation of the data by school type suggested there was no significant difference in the students' attitudes about science between the two science-focused schools. In contrast, the students enrolled in the school for the arts had negative attitudes about PSS while most of the students enrolled in the schools for the natural sciences and computer science had positive attitudes toward PSS. However, these differences could also be attributable to demographics. Unlike the students attending the science-focused schools the majority of the students attending the school for the arts were racial/ethnic minorities and poor. Previous research suggested that urban students tend to have negative attitudes toward school science programs. While the availability of research involving CSS used in elementary and middle schools is limited, this study implies that students in urban settings may benefit from science experiences that require their active engagement in social problems in their local communities.

Wolf and Fraser (2008) compared middle school students' attitudes about their learning environments and curricula in inquiry and non-inquiry physical science classrooms. Students in the inquiry labs had numerous opportunities to explore beyond the procedures, directions, and lab materials. The researchers found that in the classrooms using inquiry (open-ended) lab activities, female students were more concerned about completing the assignments correctly. In spite of the positive results from the female students' inquiry labs, female students showed less confidence in their abilities than other female students enrolled in non-inquiry labs. The non-inquiry labs were structured with clear procedures and guidelines by which girls often develop their social roles and attitudes as good students (Brickhouse, Lowery, & Schultz, 2000; Scantlebury & Baker, 2007). Male students had more positive perceptions and attitudes about the class environment in the inquiry lab as compared to the non-inquiry lab. In the inquiry lab, male students were interested in designing their own experiments and exploring items that were not part of the lab materials. As a result, male students received more attention from the teacher because they were highly prone to engage in dangerous activities, such as standing on tables to reach the ceiling. Female students showed less favorable attitudes towards their teacher when they perceived the male students as receiving more of the teachers' attention. Compared to the students in the non-inquiry labs, all students enrolled in the inquiry labs had better support systems that they developed through their peer interactions. This study along with those cited earlier, indicated a strong relationship between student attitudes, the curriculum, and learning environments.

Randler and Hulde (2007) explored a science learning environment with experiments in soil ecology. The participants included 123 fifth and sixth grade students enrolled in a German middle school who were taught by the same classroom teacher. The researchers compared different approaches to learning science such as a teacher-centered model versus a student-centered model on soil ecology where the students were taught the same science content.

Pre-tests, post-tests, and a test for retention were administered to both treatment groups. The results indicated that all students in the student-centered group scored significantly higher on the retention test and showed a significantly higher level of interest in the content. Moreover, in both treatment groups (teacher-centered and student-centered), girls performed better than boys, even though students from both groups expressed that the content was equally difficult. In general, boys expressed more boredom and perceived the task to be more difficult than girls in both types of classrooms. The results indicated that student-centered experiments and labs may provide a more effective learning environment than the teacher-centered presentations. Recommendations include teaching strategies with progressively difficult experiments or lab activities beginning in grade five. As students gain more experience with labs, more complex experiments should be introduced.

Similar to Randler and Hulde (2007), Odom, Stoddard, and LaNasa (2007) developed a survey instrument to assess instructional practices on middle-school students' attitudes and achievement in science. Their student sample included 611 seventh-grade and eighth-grade students taught by 13 different teachers in four separate school districts located in Missouri: two urban school districts and two suburban school districts. Their findings also indicated that "the more often students were exposed to student-centered teaching practices, the greater their science achievement" (p. 1340). For example, students exposed to group experiments more than once per week exhibited the greatest improvement on their science achievement.

Den Brok, Fisher, Rickards, and Bull (2006) completed a survey in California with 665 middle school science students to examine their perceptions of their learning environments. The survey asked students to assess the following items: (a) cohesiveness in working with other students; (b) teacher support; (c) personal involvement; (d) task orientation; (e) cooperation in teamwork; and (f) equitable treatment (p. 13). Den Brok et al.'s findings indicated that girls perceived their science learning environment more favorably than boys. In addition, there was a positive relationship between "the number of ethnic groups" to classroom cohesion (p. 21). Classrooms without a dominant ethnic group were perceived as more cohesive, where most students felt a sense of belonging. In general, the students perceived female science teachers more favorably than male science teachers. This research suggested the need for similar studies located within different regions, using a larger sample size, different student demographics, and qualitative instruments to explore students' perceptions of their learning environments in school science in greater depth. The next section will explore the relationship between the science curriculum and reform.

Science Education Curricula and Reform

Science education in most K-8 schools is defined by the culture of the formal classroom setting. Zacharia and Barton (2004) proposed that educators consider a critical school science program to address the needs of students who score less than proficient on national science assessments. Below, I will discuss these ideas within the frameworks of formal and informal science education.

The Formal Curriculum

The NSES (1996) emphasized the need to teach science according to frameworks that are both equitable and contemporary (Bianchini, et al., 2003; Eisenhart & Finkel, 1998; Howes, 2002; Lynch, 2000). Kesidou and Roseman (2002) examined nine middle school science programs and assessed the extent that the programs included key scientific ideas outlined in the NSES. Findings indicated that "none of the middle school programs were likely to contribute to the attainment of the key ideas" proposed in the NSES (p. 538). The programs rarely (a) provided students with a sense of purpose for the unit; (b) took account of the students’ beliefs that interfere with their learning; (c) engaged students in natural or real-world phenomena to improve critical thinking; (d) modeled using scientific knowledge to apply in everyday situations; and (e) highlighted student efforts to make meaning of key phenomena and ideas presented in class. Implications suggested a need for new middle school curricula, programs, and professional development designed to support student achievement and science literacy for all students.

To understand the success and challenges of teaching science to diverse learners, Bianchini et al. (2003) used three case studies to investigate inclusive practices, such as how the teachers implemented contemporary descriptions of the nature of science to include feminists and multicultural perspectives that involve “the lives, views, and values of women and members of underrepresented ethnic groups” (p. 421). To broaden their classroom students’ concepts of scientists, the three teachers introduced themselves as scientists with earlier careers outside of teaching and role models. In addition, all students were encouraged to view themselves as scientists as they were introduced to “thought processes and investigative practices of science” (p. 436). The teachers used student-centered strategies such as cooperative learning, open-ended investigative projects, and methods to ensure that all students participated in class activities. Two challenges to the participants’ teaching practices were (a) the time used to implement the state’s science education standards; and (b) adequate resources. All of the teachers attempted to include science reform initiatives such as highlighting contributions of scientists from underrepresented groups; planning activities to include investigative practices; and encouraging students to consider themselves as scientists. However, the teachers spent a great deal of time “locating adequate resources” (p. 436). In addition, teachers complained about the “crowded course syllabus” that required teaching specific state standards. The three teachers rarely addressed items such as “the biases that shape scientists’ research questions . . . or the knowledge and practices indigenous cultures contribute to science” (p. 436). Implications suggested the need to model inclusive practices in courses designed for pre-service teachers and the need to identify adequate resources, improve diversity, equity, and the contemporary meaning of science as a human activity with “individual, social, and institutional dimensions” (p. 421).

Friend and Degen (2007) examined the impact of school reform and policy changes in a suburban school district offering pre-advanced placement courses in English and science classes for middle school students. De-tracking and an open enrollment policy in the advanced courses were adopted to address issues in equity and access for students related to socioeconomic status. In addition, teachers in the advanced courses worked in vertical teams designed to improve collaboration and curriculum alignment that fostered progressive levels of rigor from middle school through high school. One specific goal of the pre-advanced placement program offered in the middle schools was to increase enrollment in honors and college preparatory science and English courses in high school. Results from the study indicated that open enrollment did not “impact the significant differences that exist in advanced course enrollment between low-SES students and their peers” (p. 269). Other critical elements that the district’s reforms did not address included the need for additional teacher professional development efforts that provide adequate preparation, encouragement, and support for students who are traditionally underrepresented in advanced English and science courses and parent involvement.

Informal Science Education

Improving science education, as part of systemic education reform, should also include participation from local communities such as science museums, businesses, and industry partners (NSES, 1996, p. 21). The following studies present science from the critical lens described by Zacharia and Barton (2004) through which CSS is viewed as a "social activity and involves understanding of how human values and characteristics shape scientific knowledge . . . [T]eaching and learning [science from the perspective of CSS] contain elements of action and change" (p. 201).

To understand scientific literacy and science as a system of collective activities and interactions, Roth and Lee (2002) assessed participation in an inclusive science community beyond the formal educational setting. The authors argued that the current reform movement in science education "has many shortcomings, which impede the development of achieving the goal of broad participation [and do not] sufficiently address the wide gap between school and every day, local knowledge, and fail[s] to set up a continuity of life-long learning" (pp. 51-52). Roth and Lee were interested in "ways of participating in science and scientific literacy that [did] not have boundaries coincident with formal education and life thereafter" (p. 33). More specifically, Roth and Lee's five-year research was concerned with both science and science education “where the boundaries [became] dissolved so that students and ordinary people [could] participate” (p. 33). An ecological project that focused on problems with the local watershed was designed for community participation and included activities that engaged indigenous communities, students, parents, environmental activists, municipal workers, local media, and other residents in a Pacific Northwest setting. Water from the area was contaminated from suburban development (pp. 33-36).

Middle school students enrolled in seventh grade, high school students, university students, and parents participated in the activities throughout the summer. The parent advisory council provided funding and other support for the project. Students collected data about the profile of the creek bed and designed charts for the watershed restoration which included land surveys and ownership, assessments for habitats, and tests for water quality. To promote scientific literacy in the community, one middle school student presented his findings at school, during the regional science fair, and other local events. The student’s report was one of several opportunities to reduce contaminated levels of water in the environment. The report “specifie[d] particular sites of pollution and name[d] the farms that contributed significantly to the contaminant levels” (p. 52).

However, the American Indian community expressed their reluctance to become physically involved in the project. According to Roth and Lee (2002), their reluctance may have been attributed to the “historical processes that valued Western approaches to dealing with the environment at the detriment of their own ways of knowing” through their oral traditions (p. 48). In the past the American

Indian community depended on the watershed and the wetland for food, medicine, and other materials. Implications suggested that for the local American Indian community scientific literacy was practiced as a community event, which suggested the "limitations of laboratory science as a model for broad scientific literacy" (p. 53).

Similar to Roth and Lee (2002), Buxton (2010) used an issue drawn from the local context to engage 23 middle school students in practices beyond the formal educational settings to transform and increase their understanding of science knowledge in solving real-world problems. The goal of the project was to assess the students' scientific knowledge. From a critical perspective, Buxton noted the importance of a community-based science project.

> Topics that affect us physically, socially, and emotionally may call us to action and result in the need for new knowledge and skills. [Moreover,] the current reform policy in science education that involves accountability, high-stakes tests, and standards based teaching, usually offers a generic collection of facts, concepts, and inquiry processes, organized into lengthy strings of discrete benchmarks (p. 122).

The student participants in Buxton's study were involved in structured and independent projects during a special summer program. The overall project focused on the role of drinking water and environmental health issues. In addition, students worked in pairs to create public service announcements. The setting for the project was a nature center that was run in partnership with the local school district, the city parks, and a community support group. Pre- and post-interviews were used to explore the students' understanding of water usage and water quality and a science content rubric was designed to score students' responses related to scientific knowledge. Buxton's findings indicated that all students were able to gain scientific knowledge related to environmental health. He emphasized the need for teacher training programs to include a critical awareness of social, political and economic issues associated with the students' community. Further, Buxton proposed that "critical place-based pedagogy may empower youth with a sense of competence and accomplishment, building on their strengths rather than focusing on their academic weaknesses" (p. 132).

Pre-service Teacher Training

To reduce the continuing achievement gaps in science education, Nelson (2008) argued that "pre-service and novice teachers should learn to create, implement, and support meaningful science learning opportunities for all students" (p. 235). Weinburgh (2003) investigated pre-service middle school teachers and their perceptions on the process used in the scientific method and how teachers' perspectives changed when they had experiences that expose them to the practices and processes of science as nonlinear. Thirty-two graduate students participated in the study. Twenty-seven of the participants had degrees in middle school education. Five of the participants had experience working in a research lab. The first part of this study included individual and group representations of the process used in science experiments and research. Before participating in the project, most of the participants believed that scientific investigations included a common series of steps such as (a) define the problem;

(b) make a hypothesis; (c) test the hypothesis; (d) analyze the results; and (d) draw conclusions.

The study required the participants to observe and interview a scientist regarding their current research practices and the scientific methods they used to investigate and solve problems. The scientists who participated in this part of the study worked on original projects. Some of the scientists were employed by the university and others were employed by industry. For example, one of the scientists was employed by the Centers for Disease Control to find a cure for an "exotic" fever (p. 228). Another scientist worked on a project related to nuclear reactors. After engaging in observations and interviews with scientists, pre-service teachers recognized that the scientific method or the process of scientific investigations is fluid and much more complex than they assumed.

Weinburgh concluded that the activities provided the participants with a more realistic understanding of the processes used in real-world scientific communities. The findings suggest that it is important to examine how pre-service teachers understand the scientific method and provide opportunities during and after their teacher training programs to include real-world activities with scientists as mentors and role models for science education classrooms.

Nelson (2008) examined the teacher-student interactions of 52 pre-service teachers in a K-8 science methods course by using personal reflections and analysis of video tapes to explore the extent to which pre-service teachers promoted equity in science classrooms with diverse student populations. This research focused on where and how diverse learners were excluded and included in opportunities to learn science. Another purpose of the study was to observe "whether interactions with the students created or inhibited equitable learning situations for all students" (p. 240).

Creating equitable learning opportunities was more complex than the pre-service teachers expected. While most of the teachers believed that they offered equitable learning opportunities for all students, Nelson identified gaps between the teachers' stated beliefs, intentions, and actions to implement equitable learning. For example students with special needs were often excluded from opportunities to learn. Science was scheduled when students who needed special services were pulled out of their classrooms. Likewise, the pre-service teachers' expectations were lower for students with learning disabilities, students with behavioral problems, and students who were learning English as a second language. Some participants interacted more with students whom they considered more engaging. Moreover, observations indicated that less engaged students were left out of activities and decisions. Also, teachers demonstrated a preference for interacting with certain students. For example, two of the participants tended to over compensate for the "historical exclusion of girls in science" and gave more attention to the girls (p. 244). In addition, patterns in questioning practices indicated that questions were guided toward students with higher levels of confidence and abilities. The students' opportunities to learn were "inhibited by [teachers'] preferences and expectations regarding types of children as well as some children's preferences for or resistance to engagement" (p. 247).

Findings in both studies were similar to those expressed by Williams and Lemons-Smith (2009) where “policies and practices in the school and classroom tend to worsen the ‘cultural gap’ that exists between teachers and students from diverse backgrounds” (p. 26). Williams and Lemons-Smith argued that both teacher preparation programs and professional development focus on equity and a culturally relevant curriculum that

> prepares teachers to challenge the systematic and structural inequities that exist in the school and larger community for instructional planning, decision making, and practices that . . . affirm and value the mathematics and science intellectual capacity of all students. (p. 26)

Moreover, the authors suggested that differences in achievement are the result of social practices that include the interactions of teachers, students, parents, and administrators in school systems with policies that should be designed to support achievement and progress.

Summary

The literature review highlighted the complexity of science education reform and the need to improve achievement in science literacy for all students. The current reform movement began in the 1990s to address the disproportional achievement in science education among subgroups as reported in measures of academic progress such as the TIMSS and the NAEP. As a result, NSES (1996) were designed as a guide to improve teaching and learning for all students enrolled in K12 science classrooms. According to NSES (1996) improving achievement in science education requires systemic changes that include "students and teachers; schools with principals, superintendents, and school boards; teacher education programs in colleges and universities; textbooks and textbook publishers; communities of parents and students; scientists and engineers; science museums; business and industry; and legislators" (p. 21).

Recent data from the NAEP (2009) indicated that the overall average science scores across participating states were lower for girls. In addition, white students continued to outperform black and Hispanic students. The need for addressing equity and excellence is prominently featured in the current science education reform movement.

In relationship to equity, critiques by researchers contend that science education reform proposals often do not include feminist or multicultural perspectives (Barton, 1998; Eisenhart & Finkel, 1998; Howes, 2002; Lynch, 2000). Feminists' perspectives challenge science as a school subject and "argue that it is important for children to learn to construct science out of their own interests, questions, and experiences" (Barton, 1998, p. 16). Moreover, feminists' perspectives understand the practice of science education from the view of constructivists who support the concept that science is socially constructed and students are "possessors of knowledge that will influence how they interpret new ideas, and how they accept, reject, and alter the curriculum" (Howes, 2002, p. 17).

To understand student attitudes and preferences for learning science, Zacharia and Barton (2004) developed a continuum of school science traditions. TSS, PSS, and CSS were the major categories along the continuum they used to analyze science classroom curricula. In their study, an overwhelming majority of students who were surveyed preferred a curriculum that included a critical perspective (CSS) to science teaching and learning that involved active engagement through activities related to the students' interests and community needs. Odom et al.'s (2007) study explored instructional practices on student attitudes similar to Zacharia and Barton's study. Odom et al. found that student attitudes favored instructional practices that were student-centered. In contrast, other investigations associated with student attitudes in this study used different items to measure student attitudes. For example, Jones et al. (2000) measured students' attitudes and perceptions of science and scientists. Wolf and Fraser (2008) measured student attitudes using observations from inquiry-based laboratory activities. In both studies regarding student attitudes, the term "science" was not defined. The studies by Jones et al. (2000) and Wolf and Fraser (2008) were not comparable to Zacharia and Barton's (2004) based on the instruments used. In addition to student attitudes toward school science, other researchers (Nelson, 2008; Weinburgh, 2003) explored teacher training programs.

The findings from these studies suggest that because many science classrooms include diverse student populations, pre-service teacher training programs should be designed to address differences in the teachers' stated beliefs and their actual classroom practices that "create or inhibit equitable learning situations for all students" (Nelson, 2008, p. 240). For example, Weinburgh (2003) explored middle school pre-service teachers' perceptions related to the process of science and found that the teachers believed that science was practiced with a series of discrete steps. The teachers observed and interviewed scientists who were investigating real-world projects. Participants learned that the process of science is more complex and less rigid than they perceived. The study suggested the need for professional development in real-world science projects and to include scientists as mentors for teachers in their classrooms. Nelson (2008) examined the intentions and interactions of pre-service teachers in their science classrooms. He found that students' opportunities to learn were inhibited by the teacher's expectations and preferences regarding types of students and their level of engagement in the classroom.

Science education should prepare "all students to meet high standards [and should] require equitable teaching [practices]" (AAUW, 1999, p. 77). Because gender differences still exist in science achievement, Scantlebury and Baker (2007) stressed the importance of keeping issues related to gender at the core of science education research. Likewise, teacher educators must prepare teachers to "understand the subtleties and nuances of gender effects on students' science learning and their teaching" (p. 278).

My study was designed to explore the participation of girls in their middle school science education program in a district that had a reputation for being an exemplar in science education. The girls were observed in a grade six, a grade seven, and a grade eight science classroom. Chapter 3 will describe the methods and procedures used for this ethnographic case study.

Chapter 3

METHODOLOGY

Gender inequity in science education has been the focus of researchers across disciplines since 1971. Today, many educators continue to view the fields of science, mathematics, engineering, and technology as male-dominated and seek ways to attract and retain more girls and women to participate proportionately in school courses and related careers. Social science researchers in the *Equity Equation, Fostering the Advancement of Women in the Sciences, Mathematics, and Engineering* (Davis, Ginorio, Hollenshead, Lazarus, & Rayman, 1996) argued that a variety of "socio-cultural and methodological issues emerge[d]" (p. xi) from research that identified institutional practices as barriers to the full participation of women and girls in these areas. The Association for Women in Science (AWIS), Women in Engineering ProActive Network (WEPAN), the Society of Women Engineers (SWE), and the American Association of University Women (AAUW) are leading organizations designed to advocate for public policies that promote the full participation of women and girls across all disciplines in science, mathematics, engineering, technology, and employment. In addition to these organizations, the National Science Foundation (NSF) began to fund programs for women and girls in science, engineering, and technology in 1993. In 1998 the Advancement of Women and Minorities in Science, Engineering, and Technology Development Act was passed to recognize "obstacles" associated with recruitment, retention and advancement of women, minorities, and persons with disabilities in science and engineering (The National Academies, 2007, p. 15).

Research Problem

Using one of the most current National Assessment of Educational Progress (NAEP) (2005) science scores as an indicator for performance and progress, the gender gap in K12 science education is decreasing overall in U.S. elementary schools, but increasing in some states for middle school and high school students. The southwestern state used in this study had a significant score decrease in overall grade eight performance scores from 2000 to 2005. Of all the states participating in the national assessment for 2005, the state under study had the lowest average achievement in science education. Fifty-one percent of the eighth-grade students who participated in the NAEP scored below basic on the NAEP science assessment. Twenty-nine percent of the eighth grade students scored within the basic range, 18% scored proficient, and 2% scored within the advanced range. The report indicated that nationwide, grade eight girls continued to score below boys in their science achievement. The trend in grade 12 science scores by gender also shows males outperforming females (Grigg, Lauko & Brockway, 2006). My case study was designed to explore middle school girls' experiences in their science classrooms.

Purpose

This study builds on the findings associated with gender equity and K12 science education reform detailed in Chapter 2. The study was designed to examine the complex perspectives, social interactions, and other meanings

(Glesne & Peshkin, 1992) associated with science education reform and the context for middle school girls' participation in science.

This ethnographic case study also represents an effort to give voice to a group whose members are often overlooked, middle school girls, by using their personal classroom science journals to explore their perspectives of and social roles in science and how they view the school's role in promoting their science achievement. The girls' experiences in their science classrooms were used as one "test of adequacy" (Harding, 1987, p. 11) to explore their experiences in middle school science education. The research problem began with women and their disproportional representation in science education and related professional careers. The intent of the study was to understand the experience and participation of girls in their middle school science program. Below, I describe the research method and design, setting, participants, researcher's role, procedures and materials, data sources, and methods used in the data analysis.

Method

To explore the attitudes of middle school girls regarding science education reform, I conducted a case study of Riverside Middle School. Merriam (1998) noted researchers often used the case study design to "gain in-depth understanding of the situation and meaning for those involved" (p.19). According to Yin (1994) the advantage of case study research is that it provides a holistic view of participants in a real-life context with multiple sources of evidence. Using different data to measure the same phenomenon increases the case validity (pp. 91-92). The focus of the case study was the context for teaching and learning science in middle school.

The interpretive study included the techniques of ethnographic research. The basis of interpretive research is the assumption that participants and the researcher co-construct reality in their social interactions (Glesne & Peshkin, 1992). In this study I attempted to assess the cognitive and sociocultural aspects of the middle school science lessons that I observed from multiple perspectives. Middle school as a culture, has a system of "socially constructed meanings," (Spradley, 1980, p. 9) that are learned, revised, maintained, and defined through the social interactions of the actors in that setting. Ethnographic approaches to research involve an effort to understand the social environment through the observations of what the participants do, what they say, what they make, what they think, and what they use. Learning from the participants in a middle school as a subculture of the Valley View Elementary School District, involved a search for patterns inside and outside of the science classroom to understand how the setting shaped their views of equity in science education reform. A description of the setting follows.

Setting

The Valley View Elementary School District was established in 1888 to serve the children of farmers, farm workers, and dairy owners. In the 1970's enrollment began to rapidly increase because of the growing technology industry. In 1985 the district's student enrollment almost quadrupled (Anonymous, 1995). With the growth of high technology industries, Valley View has changed from rural to suburban and serves the children of many professionals who are employed in technical careers.

At the time of this study, more than 19,000 students were enrolled in kindergarten through eighth grade at Valley View School District. The district consisted of 20 K-5 elementary schools and six middle schools. Valley View is one of the top performing school districts in the state. Its achievement in reading and math has been consistently above the state average. This high-achieving school district was involved in a high-profile effort at improving girls' participation in science. In 1993, the school district established goals to concentrate teaching and learning activities on math, science, and technology, using industry collaboration. Valley View worked in partnership with a major corporation to support initiatives designed to facilitate learning and achievement in math, science, and technology.

The research site under observation was Riverside Middle School. The school opened in 1992 as the fourth of six middle schools in the Valley View School District. Riverside enrolled approximately 1,000 students. More than 300 students were enrolled in each of the grades six, seven, and eight. The student racial diversity at the school at the time of this study was as follows: Asian 7%, African American 7%, Hispanic 10%, Native American 2%, and White 74%. Compared to the state average, the racial demographics at Riverside were slightly higher for both the African American and Asian populations (U. S. Census, 2000). At Riverside, more than 57% of the teachers had 10 or more years of teaching experience. Seventeen percent of the teachers had three or fewer years of teaching experience.

I arrived at the Riverside Middle School campus for my first day of fieldwork on a Monday morning and parked in the visitor's lot, near the front entry. Parents and grandparents drove modern Sports Utility Vehicles to drop off their children and grandchildren. Cars lined the pavement waiting for someone to unlock the school's gate. As I waited with the students and their families, I took a moment to focus on the setting for this research.

The school is located in a comfortable middle class community. The lawn in front of Riverside Middle School was well-manicured with grass, cacti, bougainvilleas, palm trees, and other desert plants. A few of the awnings were painted in a medium red, gray, or royal blue color. The colors added a layer of vibrancy to the landscape in front of the Saguaro foothills and mountain range. The campus has four buildings. The administrative building, two classroom buildings, and the multipurpose building are set on approximately three to six acres of land. The administrative building included the main office, the principal's office, and two offices for the assistant principals, a counselor's office, the staff lounge, and the school's bookstore, which is located on the northeast corner of the building. The bookstore sold t-shirts with the school mascot -- the "Desert Reptiles," paper, pens, pencils, snacks, and other fun items for adolescents. Students were only allowed to make purchases at the bookstore in the morning before school, during lunch, and after school. The two classroom buildings were located on the southwest of the administrative building. These two-story buildings housed two to three pods or sections within the three grade levels-- sixth, seventh, and eighth.

The science classrooms for grade six and grade seven were designed as regular classrooms. There was no space provided for student lab stations. The small classroom for grade six had a counter top and sink with a faucet for running water located on a back wall. The room was set up with three rows of small tables and chairs. In grade seven, the classroom had one teacher station for demonstrations located in the front center of the classroom. There were nine rows with four regular student desks in each row. The seventh-grade classroom was extremely small. There was less than a foot of space between each row of desks. The eighth-grade classroom had nine large tables with chairs for three to four students. In the eight-grade setting, there was one teacher demonstration table located in the front center of the room and eight student stations. The eighth-grade classroom had the largest amount of space for completing science labs and projects in a comfortable learning environment.

The classrooms were located in separate pods. The pod concept is commonly used in middle schools to address the needs of early adolescents. The pod system creates small communities to share curriculum, instruction, and develop a social environment for students ages 11 to14.   For example, the grade six teachers and students were housed in Pods 6A, 6B, and 6C. The grade seven and grade eight teachers were located in pods similar to the grade six teachers. Another goal of the pod system was to provide a context for deeper interpersonal relationships between and among students and staff. This system includes essential components such as interdisciplinary teams, block scheduling, and exploratory curriculum. Special classes such as multimedia and dance are offered outside of the pods. Each pod in this study had three to five homeroom teachers. The teachers worked as a team to plan and teach the same students. Students attended their core classes— English, science, social studies and math within a Pod assigned to them. Most students remained in their Pod until the school year ended in late May. Below is a description of the participants.

Participants

As noted above, Valley View Elementary School District was one among several school districts that participated in the WISE Investments program. Valley View held a unique position in the program because it had the largest representation of participants. Several teachers from the district were involved in the summer workshops. Moreover, throughout the entire program more girls from Valley View enrolled in the Saturday hands-on engineering labs than from any other school district.

This case study at Riverside Middle School grew out of my relationships with the sixth-grade science teacher and the technical educator whom I met during the WISE Investments summer workshop. Because of the sixth-grade science teacher's involvement with WISE Investments, I expected high levels of engagement in science and engineering in her classroom. Moreover, I wanted to feature Riverside as another model or "promising case" (Rodriguez, 2001, p. 1115) for science achievement with middle school girls.

The case study included 34 participants from Riverside Middle School: 19 girls, 10 parents, three science classroom teachers, one counselor, and one administrator. Mr. Clarke, the grade seven science teacher was the only male participant. The school principal chose one science classroom at each grade level for which I was a participant observer. Each of the three science teachers chose one of their favorite science units and their most diverse classroom for the case study. As stated earlier, I met the grade six science teacher in the WISE Investments summer professional development program. It was her grade six science classroom that I observed. At the same case site, there were two science teachers in grade seven who also participated in WISE Investments, but they were limited only to the role of informants (Glesne & Peshkin, 1992; Yin, 1994). Next is a description of my role.

The student participants included seventeen female students from the classrooms that I observed: ten students from grade six; six students from grade seven; and one student from grade eight. Because there was only one female student participant from the grade eight classroom, I shadowed two female eighth grade honor students. I attended their honors math class at the local high school, elective classes, lunch, and recess periods. I met these two students several months before this study when they participated in the WISE Investments Saturday Academy. Next, I will discuss my personal role in this study.

The Researcher's Role

I have a professional background in career and technical education, special education, and high school administration. I have taught in urban high school districts for more than two decades. This case study was an opportunity for me to explore science education and gender equity in a middle school context. My initial interest in this study grew out of my involvement as a graduate student working in the Women in Science and Engineering (WISE) Investments program. WISE Investments was a university-sponsored partnership with the National Science Foundation (NSF) and the College of Engineering and Applied Sciences at a major university. The goal of the program was to increase the participation of girls and women in non-traditional careers related to science and engineering. I worked with the primary investigator of this NSF funded program as the assessment assistant and later as a team member to develop and coordinate the summer professional development workshops for middle school and high school educators.

The summer workshops introduced middle school and high school science teachers, math teachers, and counselors to eight fields of engineering (chemical, industrial, materials science, aerospace, electrical, computer systems, civil, and bioengineering). Key concepts associated with gender equity and hands-on activities in engineering were taught to school teams of middle school and high school science teachers, math teachers, and counselors. The goal of the summer workshops was to help the teams integrate the concepts and activities introduced in the eight fields of engineering into the schools' science and math curricula with engineering. The counselors were strongly encouraged to use the engineering resources to introduce female students to nontraditional careers that were held by women in science and engineering. The teachers and counselors had additional opportunities to experience the real world of engineering with engineering internships sponsored by local industries. The university's engineering faculty and the industry partners became mentors for the teachers throughout the school year during which they were involved with the program.

During the academic year, middle school girls enrolled in the WISE Investments' Saturday Academy. All participants in the summer professional development workshops worked in teams to teach eight engineering concepts to students enrolled in the Saturday Academy. One Saturday Academy was held each month to introduce one of the eight engineering concepts with hands-on activities for the middle school and high school girls. Female engineering college students mentored the girls on Saturday morning with discussions and tours of their academic and dorm life on campus. During the week days the female college students hosted field trips to various engineering industries.

As the staff who worked with the WISE Investments program and I reviewed the data from the Saturday Academy, we found one school district involved in the program maintained a significant enrollment of middle school girls throughout the three years of the grant. On one occasion, the program coordinator and I were invited by parents and members of the school district's governing board to celebrate the middle school girls' participation in the WISE Investments program. At the board meeting I became interested in the Valley View Elementary School District as a focal point of inquiry for middle school girls and their science achievement. Two students, one computer lab instructor, and three science teachers from Riverside Middle School were active participants in the WISE Investments Program.

During the study, my role ranged from a full observer to a participant-observer (Glesne & Peshkin, 1992, pp. 40-41). Initially, I felt like an outside spectator as I observed classrooms and other locations throughout the campus. As I became familiar with the middle school environment, “the mix of participation and observation” (Merriam, 1998, p.103) began to change. For example, during Engineering Day in grade six, I volunteered to call parents to document approval for students to release photographs and participate in interviews with the local media. There were other occasions during the science and engineering labs when I interacted with both participants and non-participants. I helped teachers to set up materials and student displays. I also judged the team competitions. My role in these settings allowed me to build rapport with both the teachers and the students. For example, a boy in grade six asked me to help him with the potting soil for his classroom science experiment with plants. In grade seven, I helped students with their computer software to examine earthquakes. My participation in these “social situations” (Spradley, 1980, pp. 52-57) allowed me to feel more like an insider. During the data collection, I also participated in a professional internship with the school district’s superintendent.

Procedures

I spent five months at Riverside Middle School observing, interviewing, and interacting with teachers, students, parents, and staff. I collected data three to four days per week. Consent to participate in the study was required in writing from the school district, the principal, and the parents. The study also required written assent from the student participants. Data sources for this case study included field notes, assessment guide, campus and classroom observations, pre- and post-observation interview transcripts, student science journals, focus groups, and school artifacts. My field notes were taken at various locations throughout the campus during lunch or passing time and during the classroom observations. The notes included descriptions of the environment, documentation and jottings from informal and formal events, classroom diagrams, personal thoughts, and other information considered key to the case study (Bernard, 1994; Glesne & Peshkin, 1992; Merriam, 1998).

To assess gender equity at the school and district levels, I designed a scale to rank the level of equity in course enrollment patterns, curriculum, counseling, achievement in science by gender, and the learning environment. The principal, counselor, and the three science teachers completed a questionnaire using the scale. The statements were adapted from the Gender Equity Assessment Guide, Initiative for Educational Equity (American Association of University Women, 1992). The protocol used for the assessment of gender equity at Riverside is located in Appendix A.

In addition to the equity assessment, I used focus group interviews to discuss and explore the perceptions, feelings, and attitudes on gender and science education from key groups of participants. All focus groups were held before the school day and before I began the formal classroom observations. The questions were semi-structured. Two focus group interviews were conducted for the parents of the participants, one for grade six and one for grade seven. There were no parent participants for grade eight. During the parent focus groups, I wanted to capture the parents' general perceptions related to their daughters' interests, participation, and achievement in science at home, at school, and in the community. The Parents' Focus Group Protocol is located in Appendix B.

I also conducted two focus groups with the female student participants, one for grade six and one for grade seven. There were no participants for grade eight. The focus groups for the student participants were created to compare their responses to those provided by their parents. The questions were similar to those used in the parent focus groups. I wanted to find patterns and trends across the groups (Krueger, 1994, p. 17). The Girls' Focus Group Protocol is located in Appendix C.

To understand the teachers' experience and training in teaching science, I held pre-observation interviews. During the pre-observation interview, the teachers decided the specific science unit for my study along with a diverse class of students for the formal observation. The interviews were audio tape-recorded and transcribed. Before the formal classroom observations, I was also allowed to conduct informal observations of each classroom setting. The protocol used during the teachers' pre-observation interview is located in Appendix D.

Formal classroom observations began at the request of the teachers. My formal classroom observations focused on science classroom instruction and the participation of middle school girls during their 40-minute class periods. The length of each science unit was approximately two weeks. After the formal classroom observations, I conducted post-observation interviews with each teacher. The questions were semi-structured and the interviews were audio tape-recorded and transcribed. The questions used during the post-observation interview are located in Appendix E.

Each of the female student participants in grades six, seven, and eight were asked to keep a personal journal of their thoughts, attitudes, and comments for several days of the unit of science instruction. The first day of the science unit, several intermittent days, and the last day of the unit were essential to my study. I designed the student journals with six writing prompts for the first day of the science unit; three writing prompts for days two, three, and four; and eight writing prompts for the final day of the science instructional unit. The title of the 11 x 8½ journals was *Thinking About Science*. Twelve pages of the science journals were created digitally. The cover pages were designed with age appropriate graphics to distinguish each grade level. The next page contained the 17 writing prompts for the science unit I observed. The writing prompts were created to assess factors that might affect female student performance and participation in science (Clewell & Ginorio, 1996; Sanders, Koch, & Urso, 1997). After the prompts, ten lined pages were included for students to write their responses. A sample of the Student Journal Protocol is located in Appendix F.

Artifacts included examples of student assignments, handouts, science textbooks, the district's science curriculum guide, school newsletters, the community newspaper, district partnership documents, and other digital resources. Students' assignments and handouts are discussed in detail in

Chapter 4. References to other artifacts are located throughout the study.

Data Analysis

To analyze the data I used Miles and Huberman's (1994) *An Expanded Sourcebook, Qualitative Data Analysis* and Merriam's (1998) *Qualitative Research and Case Study Applications in Education*. I designed a coding scheme, set up categories, and displays for each of the data sources. The coding scheme was used to identify the grade level, artifact, and participants. To identify patterns and trends, I used categories to index the sources of data along with digital tables to display the data within each of the categories. These role-ordered displays helped me to set up a system for comparisons. For example, the Gender Equity Assessment Guide used in the early part of the data collection was coded by participants (i.e. principal, counselor, and teachers). Participant responses to the questionnaire were displayed by item numbers and themes. The data entered in each cell provided a summary of the participants' perceptions (Miles & Huberman, 1994, pp. 123-124).

Data was analyzed simultaneously with the data collection. The multiple sources of data such as interviews, questionnaires, observations, student journals, artifacts, and other documents were used as evidence to increase the validity of the research design. In addition, I used both peer and participant reviewers to identify inconsistencies and inaccuracy in my reports. In the final stage of the analysis, I triangulated the data by reviewing and analyzing all the data sources together to look for contrasting perspectives that both confirmed and disconfirmed my conclusions.

Methodological Assumptions

Several research studies on girls' attitudes, achievements, and perspectives in science education have been conducted in urban settings (Baker, 2002; Baker & Leary, 1995; Brickhouse & Potter, 2001; Farland-Smith, 2009; Hewson, Kahle, Scantlebury, & Davis, 2001; Rodriguez, 2001; Zacharia & Barton, 2004). In contrast, the setting for this study took place in a suburban location in the southwestern United States. Yin (1994) argued that the results of a case study research provide some opportunities for generalization, however the insights from a given case study may not hold in settings with different conditions and populations. This case study can be used as a foundational guide or resource for future research.

As noted earlier, reports from the NAEP (2005, 2009) science scores are used as indicators of progress in science education. The scores in the reports are disaggregated by gender, culture and race/ethnicity, and reported only for grade four, grade eight, and grade twelve. The primary focus of this study is the perspective of middle school girls in grade six, grade seven, and grade eight. Why choose a middle school? The AAUW (1996) report, *Girls in the Middle: Working to Succeed in School*, indicated that "[g]irls' self-esteem and confidence in their competence, particularly in regard to math and science, drop precipitously during their middle school years, narrowing their later choices of course work and career path" (p. 2). In this study I explore how these phenomena may be related to girls' experiences in their middle school science classrooms.

Summary

Chapter 3 contained an overview of the research methods, design, and other attributes to define the study. The setting for the study was a suburban school district in the southwestern part of the United States. The purpose of the case study was to explore the experiences of middle school girls in their science classrooms. The 34 participants included middle school girls, their parents, science teachers, a counselor, and the school principal. The data collection process consisted of interviews, observations, a questionnaire, field notes, documents, and artifacts. Chapter four includes a detailed description of the findings.

Chapter 4

DATA ANALYSIS

This chapter summarizes the results and findings of the data collected from a questionnaire, school and classroom observations, interviews, student journals, artifacts, and focus groups. Other results from the data are presented for grade six and grade seven, respectively. I begin this chapter with the data sources.

Valley View Elementary School District, K-8 elementary school district, located in the southwestern part of the United States, was chosen as the site for this study because of its participation in a university sponsored program for the Women in Science and Engineering (WISE) Investments. Because Riverside Middle School, the case study school, was less directly involved in science reform activities than other schools in the district, my analysis provides insights into how, if at all, high-profile reform efforts shape activities across the schools in a district that had particularly high and active participation in a reform aimed at increasing gender equity in science.

Questionnaire on Gender Equity

To explore the middle school's system along with the context for gender equity and science education at Riverside, I designed a close-ended questionnaire with a rating scale (see Appendix A). The responses included perspectives from the principal, counselor, and the sixth, seventh, and eight grade science teachers whose classrooms I observed. The principal was selected as a participant because she was the educational leader responsible for the overall school science program, such as approval of the curriculum and professional development. In addition, the principal supervises staff and manages policies and procedures. The counselor was selected because she conducted assessments and provided academic and career guidance to students for selecting courses at the high school. The teachers were selected because of their direct relationship with the student participants enrolled in their science classes.

The questionnaire used to assess gender equity at Riverside was adapted from the Gender Equity Assessment Guide (1992) that was created by the American Association of University Women (AAUW) to assess gender fairness in school systems. The guide was designed to determine if immediate action or only minor changes were needed for programs in a specific area such as curriculum, counseling, or professional development. The questions covered the following categories: (a) course enrollment patterns, (b) counseling for girls on courses and careers in science and math, (c) professional development related to gender equity, (d) curriculum bias, and (e) the learning environment. Respondents were asked to rate procedures and practices for gender fairness in science at the school and district levels on a five point scale denoting the degree they believed these policies were implemented. The participants were asked to indicate if they believed policies on gender fairness: (a) were written and fully implemented; (b) were partially implemented; (c) in the process of being written; (d) the district or school had given some consideration to gender fairness; and (e) the district did not have any procedures in a given area.

On the question related to course enrollment patterns, the teachers indicated there were procedures in place for both the district and the school to identify students' course enrollment and achievement patterns in science and math by gender, ethnicity, and disability. However, the principal and the counselor responded there were no procedures to identify patterns in students' course enrollment and achievement. When asked about the gifted and advanced science courses, all participants agreed there were no procedures to offer these types of science courses in the district. On another question about implementing procedures associated with encouraging girls through counseling to continue their studies in science and math, the principal indicated that procedures were fully implemented, but the teachers and the counselor responded there were no procedures. Interestingly, the counselor's written response suggested that counseling opportunities in STEM were available through a partnership with the local university. In addition, the counselor reported that she provided voluntary programs for girls to participate in career pathways, but she did not indicate that the careers included nontraditional options for girls aligned with careers in STEM fields.

On a question related to professional development and practices in science education, only one of the five participants, the principal, expressed that procedures were fully implemented for district and school employees to receive training related to gender fair practices in teaching and learning science. The response patterns suggested the three teachers and the counselor were not aware of professional development opportunities addressing gender equity in science education.

Questions about the curriculum addressed procedures to review textbooks and other teaching materials for sensitivity to diversity and gender discrimination. The participants' responses indicated that at the district level there were efforts to examine and purchase materials that reduced bias. In response to the question on the learning environment, all participants indicated there were "partially implemented procedures" for the staff to demonstrate high expectations for all students regardless of gender, disability, socioeconomic status, ethnicity, or religion. Two of the three teachers expressed programs were available at the district and the school levels associated with mentoring and job shadowing to improve gender fairness. The counselor indicated there was only "consideration" to include mentoring at the school. The principal and one teacher reported there were "no procedures" in place for mentoring and job shadowing. Overall, the participants' responses to the Gender Equity Assessment involving course enrollment patterns and achievement, professional development, counseling, and mentoring may suggest a need for training on the various opportunities available through the district to support practices in gender fairness.

Summary

While it is important not to over-generalize from such a small sample of respondents, the results from the questionnaire on gender equity were mixed. There were no clear indications that the participants agreed on items that assessed school policies, procedures, and practices used to promote gender equity in science education at Riverside Middle School or the Valley View Elementary School District. Nor were there clear patterns in the responses asking respondents to assess the degree to which the policies, procedures, and practices were being implemented. In the sections below, I describe and analyze some typical science units that were taught at Riverside. Mrs. Jones, the sixth grade teacher taught a lesson on plants and ecology. Mr. Clarke, the grade seven teacher taught a unit on geology. Mrs. Hamilton, the grade eight teacher taught a unit on genetics. As I explain below, the teachers characterized these units as among their favorite units to teach.

Grade Six Science Instruction

In our pre-observation interview, Mrs. Jones noted that teaching about plants and ecology was her favorite unit because of her "passion for nature and our environment." She described wanting to share this passion with her students so they would care more about the world they lived in. Mrs. Jones taught this unit for approximately two weeks. The students recorded journal entries on four intermittent days during the two weeks of this science unit.

Grade Six Observation Day One

On day one of the observation, there were 27 students present: 12 girls and 15 boys. Mrs. Jones' gestures and the tone of her voice suggested that she wanted her students to enjoy the unit. She gave her students several opportunities to participate in the lesson through student discussions and setting aside time for questions and answers. At the beginning of class, Mrs. Jones held the students' attention by telling them a story of this "weird-looking thing in [her] backyard" and quoted her husband as saying, "this unusual-looking thing is a seed." Mrs. Jones described the seed as an "ugly acorn with extensions growing around it" and added that her husband told her, "one day that weird-looking seed would grow into a beautiful palm tree." A male student spoke out, "we decorate those palm trees for Christmas." The teacher's excitement appeared to be contagious because I overheard two girls express their interest in the labs and working with each other as lab partners during the unit on plants.

Mrs. Jones framed her introduction to plants with two questions – "Why in the world do we study plants? What are they good for?" Several students expressed their thoughts simultaneously. One female student raised her hand to answer the questions. Mrs. Jones acknowledged the student after she reminded the class to raise their hands. The student responded, "For food." Mrs. Jones confirmed the student's answer and added, "one major concern for studying plants is for food. People and animals need food to live. When the food that we eat is digested, it produces energy that keeps us active and productive. Another essential fact is plants need carbon dioxide to grow. Plants act as a filter to clean the air we breathe."

Next, Mrs. Jones gave each student a four-page handout on plants and used the projector and transparencies to review the handout. The handout consisted of ten subtitles and nine diagrams. Mrs. Jones asked her students to listen, read, and highlight key points that may be used on their unit exam.

The first section on the handout was entitled "Plants with Seeds." Above the subtitle on the right was an illustration displaying a seed that was split in half. Mrs. Jones called on a male student to read the brief description of "Plants With Seeds." Next, Mrs. Jones asked the class to highlight the most important fact on the handout, “Seed plants are some of the most numerous plants on earth.” Mrs. Jones asked three students to name one seed plant. A male student said, “apple tree.” Many of the students laughed, when Mrs. Jones responded that the student’s comment reminded her of Johnny Appleseed. A female student added, “strawberry” and a male student added, “orange.” Mrs. Jones wrote the three responses on her transparency in the spaces created for this purpose. She asked the students to do the same on their handout. Mrs. Jones completed her discussion of the first section by telling the class that the “stems and leaves are included in the seed.”

The remaining three sections of the handout contained a mixture of text, diagrams, and spaces for students to fill in. Mrs. Jones discussed these sections much like she did with the first section, asking students to fill in the blanks where appropriate and highlight key pieces of information. However, she briefly departed from the handout and attempted to engage the students with a personal story in the discussion of roots in section two when she made the following comment to her class: “We like to eat roots– pretty weird isn’t it?” After noting that “fibrous roots are like tangled roots.” Mrs. Jones told a story about herself. One day, when she was a lot younger, she was out in the park with her family. She remembered sitting on the ground picking at the grass. Young Mrs. Jones pulled up a patch of wet grass with mud dangling from the roots. Some dirt was also hanging onto the mud and roots. She became embarrassed about the earth that she exposed, so she returned the patch to the ground and patted the grass in place. Relating this story to this science unit, Mrs. Jones explained that the grass was held in place by “fibrous roots.”

Likewise, in the discussion of tap roots, Mrs. Jones began with a demonstration of Bugs Bunny. She made a smacking sound with her tongue and lips and asked ---“What’s up Doc?” She asked the class, “What is a tap root?” Mrs. Jones repeated her rendition of Bugs Bunny. Instead of the smacking sound, she tapped the table and explained that her example of tap roots was a carrot. “Potatoes and carrots are roots that store food. We like eating a loaded root – [like baked potatoes and] French fries, (pause) eating a fried root.”

The students read brief descriptions from the handout about fibrous roots, tap roots, and the different layers of the root. After the students completed the reading the teacher asked the following question: “What do we know that has an epidermis? A young man answers, “We do. It’s our skin.” Mrs. Jones emphasized that the outside of a root is called, “the epidermis.” She explained that the root has a cap to protect it. She gave an example of a capped tooth. After her example she described the cell-like structures inside the plants’ root called the xylem and the phloem. Mrs. Jones told her students that people make a career from studying plants. “Researchers, for example, used corn to discover genetic makeup, heredity, what things are made of, and how things are reproduced.” The students highlighted key points and completed the five blank spaces on their handout. Mrs. Jones called on three female and two male students to identify the five answers outlining the cross-section of the root: epidermis, root hair, phloem, xylem, and root cap.

The teacher closed the section on roots with five oral questions, such as "what is the function of the root" and "name one type of root and give an example." The majority of the responses (five out of eight) were given by male students.

Mrs. Jones began the next part of her lecture from page three of the handout. There were three sections: (1) *Stems;* (2) *How do plants transport food?* and (3) *How do plants transport water?* She began by stating, "Like roots, stems have purpose. They have a phloem and xylem to carry minerals and water to the stem." Next Mrs. Jones asked a question, "What do cactus store? The class responded like a chorus, "water." She acknowledged their response and continued, "Stems contain the phloem and xylem. They carry minerals and water. Stems separate leaves to intake both air and water."

Mrs. Jones described two groups of plants based on the stems: herbaceous plants and woody plants. For herbaceous plants, she asked her students to "think soft and green." A female student asked, "Do we highlight the word soft?" A male student interrupts her and asked Mrs. Jones, "If we have a test, can we use the word-- soft?" Mrs. Jones answered, "yes." A male student asked, "Are the stems on the woody plants called trunks?" Mrs. Jones responded, "Yes, I want you to understand the jobs of stems. Highlight exactly what I have: stems and phloem. It is important to remember food and phloem go hand in hand. It is like a straw but, the phloem is a living cell. It is open at both ends which allow it to carry food." During this exchange, two male students demonstrated the function of a straw by curling their fingers into a fist, with the small finger resting on the table and sucking through the top opening created by the index finger and thumb. The class started to get noisy because it was close to the end of the day's lesson. Mrs. Jones reminded her students, "We are not done. I have 'Front of the Line' (FOL) Passes and 'Desert Reptile' Slips (D-R Slips). I also need my highlighters back." She had the students put away their papers to prepare for closure with the day's lesson. The FOL Pass was a weekly note card for students to be the first person in line when leaving the classroom. The D-R Slips were coupons used to purchase items in the school's bookstore.

To reward D-R Slips, the teacher asked two questions. The first was, "What is the outside (layer/skin) of the root called?" After a brief pause, a male student answered, "epidermis" and received a D-R Slip. The second question asked a student to name plants that produce seeds. Another male student answered, "apple, orange, and strawberry" and was awarded a D-R Slip. To award FOL Passes, Mrs. Jones asked seven questions: "Name all three functions of a root." Four female students and three male students answered the questions correctly and received FOL passes. In one of these exchanges, Mrs. Jones asked the class, "Think and tell me how a plant transports food." A male student responded that he needed more details and then a female student offered the correct answer: "Plants transport food up and down in the tubes that are living cells."

Mrs. Jones ended the lesson by assigning homework. She wanted her students to look at their house plants and be prepared to discuss what they observed about the plants. She encouraged the students to tell their parents what they were doing in their science class. For example, when a student sees their dad eating carrots or potatoes, Mrs. Jones wanted her students to say, “Dad, you are eating a tap root!”

On the first day of the unit on plants, Mrs. Jones included her personal stories, a lecture, note-taking with highlighters, and opportunities for student discussions along with several review questions. Students were provided many opportunities to participate, ask questions, and receive rewards for their correct responses. Mrs. Jones engaged her students with a combination of strategies for learning science. Using Zacharia and Barton’s (2004) continuum for School Science Traditions, I identified two of the three models for teaching grade six science. Mrs. Jones’ used both lecture and rewards that are consistent with teaching for objective information under the Traditional School Science (TSS) model. Her focus on student discussions for conceptual understanding was not typical of the approach for teaching under the model for Progressive School Science (PSS), where emphasis is placed on student perspectives. Mrs. Jones asked the students to respond to specific questions rather than really inviting them to participate and solicit their perspectives. There might have been moments (such as the story she opened with), that had the potential to develop into a more open, student-oriented discussion consistent with the PSS model, but I suspect that Mrs. Jones’ use of the handout discouraged students to share their perspectives. After class, ten female student participants were asked to respond to six questions in their science journals. In the section that follows I analyze the students’ perspectives.

Grade six student journals—day one. Question one was designed to assess the participants' level of prior knowledge on plants (see Appendix F). Because the district's Science Curriculum introduced plants in grades K-5, I thought students with prior knowledge on plants would be actively engaged in discussions and critical thinking. As the students added more information to their skill set, they would increase their level of confidence in this strand on "Living Things." Three of the ten participants stated that they knew very little information on plants. The following statement is one example: "I did not really know anything about plants, but they have a stem, leaves, and petals." The other participants gave examples of what they knew about plants. One student wrote:

> I knew a lot about plants in general because I had one a unit on them in 3rd grade. In 3rd grade I had to plant a plant and water it. During this unit I learned about the different parts of the plant and what they do, in general. We did not nearly go into it as much as we did today. I also knew about the different parts of the seed. In third grade, along with 4th and 5th I learned a little about photosynthesis, but just that it was a process in which plants use sunlight, chlorophyll, carbon dioxide, and water to make food not really how they do it.

I designed a rating scale based on the number of examples provided by the students as shown in Table 1. Using this rating scale, more than two thirds of the respondents had a low level of prior knowledge related to the unit on plants. Although many of the participants from this sample had previous exposure to the unit on plants, they cited few specific examples of previous knowledge.

Question two gave the students an opportunity to express how they felt about the lesson. It also gave the students an opportunity to suggest ideas to make

Table 1

Rating Scale

Rating	Response	Examples	# of Participants
High	Affirmative	≥ 9	1
Average	Affirmative	8 – 5	2
Low	Affirmative	≤ 4	7
Total			*10*

the lesson more interesting. The students had mixed reactions. Three students implied that “nothing could have been added to the lesson.” One student’s brief reaction to the lesson was positive: “[Our] teacher explained clearly and gave examples for understanding [her lecture].” However, two students were more critical about the lesson. One of these wrote, “The lesson was boring. We highlighted important notes. The notes were interesting [and] the D-R Slips were cool.” Another student said the first day was “blah.”

Six students provided suggestions for what could have been added to the lesson. Four students indicated, “projects, labs, and hands-on activities add fun, and excitement.” One student appeared to enjoy Mrs. Jones’ stories. She wrote, “Tell more stories about the unit, and at least one fun and interesting activity.” The last student wanted more factual information. She wrote, “Tell what seeds are made of.” These brief responses do not suggest a high level of engagement. For example, two students seemed engaged in the unit which suggested they liked Mrs. Jones' lesson format. Three of the students were bored or ambivalent, and the others reported wanting to participate in more interesting activities related to the unit.

To assess the students' level of confidence for understanding scientific concepts and their lab experiences, I asked what letter grade they expected to receive on the unit. Some of the participants wrote multiple grades. For example, one student expressed, "I would like to get an "A", "B", or "C." Overall, the students' responses suggested that they were confident in either their science abilities or their ability to do well on the unit to receive a passing grade. However, these students may have wanted to perform better because they were the primary focus of this study. Table 2 shows the grade distributions provided by the students.

Table 2

Anticipated Grade for Unit

	Grade A	Grade B	Grade C
Number of responses	9	6	2

Students used multiple answers to explain how they planned to earn a passing grade. Their framework for success included 21 responses. The most frequent items were: "work hard to complete assignments"; and "listen/follow instructions." Table 3 represents the participants' framework for success.

The students provided at least two and as many as eight examples of what they learned for a total of 39 responses. I used the rating scale shown in Table 4 to rank the number of examples given by the participants from high to low.

Table 3

Framework for Success

	Complete assignments	Follow directions	Study for quizzes	Actively participate
Number of responses	7	6	3	3

Table 4

Number of Items Learned

Rating	Number of examples	Number of participants
High	9 ≥	0
Average	8 – 5	3
Low	4 – 1	6
NA	≤1	1
Total		*10*

All of the student participants reported learning the purpose of stems, roots, and how plants get food. One student reported:

> I learned about seeds, and the many different plants with seeds. I learned about the three functions of roots. The one thing I really didn't know about roots was that all the extra food is stored there and becomes a starch. I also learned that minerals and water move through a tube called xylem made of non-living cells.

Many of the students' examples were written at the recall level of higher order thinking skills which indicated a basic level of engagement. Moreover, it suggested that the instruction was framed using the TSS model.

All student participants responded with brief comments related to the teacher's instruction. One student stated

> Today's lesson was one of the best lessons I had in science this year. [The teacher] was excited about what she was teaching and wanted us to be excited about it also. She puts a lot of effort into helping us learn this unit in a fun and exciting way.

However, this student did not provide examples of the fun and exciting activities used by the teacher.

Seven of the ten students expressed or implied a positive attitude toward the lesson. One student stated, "The information will help me study for the test on this lesson next week." Teaching and learning science for test information is typical of Zacharia and Barton's (2004) TSS model in which the assignments are designed for recall information.

Three students did not respond with positive feedback. One student thought the lesson was "kind of boring." One student expressed a lack of confidence in learning science. She wrote, "I don't like science because it is hard and I don't get anything." Another student appeared to be disengaged. She responded, "I'm not that into plants."

Overall, Mrs. Jones' introductory lesson to the unit on plants received mixed responses from students. The students' engagement ranged from interest in the teacher's personal stories with plants and a need for more information to disengagement (non-interest) to a lack of confidence in understanding science. Next, are my observations and participant perspectives from day two.

Grade Six Observation Day Two

The science lesson for day two included a class review, a lab, a lecture, and a second review. During the review of the previous lesson, Mrs. Jones called on students randomly to answer her questions. She used verbal cues and rewards (FOLs and D-R Slips) to encourage correct responses. Although I did not expect her to do so, Mrs. Jones gave FOLs to the girls who wrote in the science journals used for this study.

To introduce the lab, Mrs. Jones explained and drew a diagram of three lima beans (seeds) placed on a wet paper towel. She gave each table one cup, two paper towels, and three seeds that had been soaked overnight in water. The class was asked to place one of the paper towels in water. After this, Mrs. Jones had the students arrange the seeds in different directions and fold the first paper towel into a tube-like shape. The students lined the cup with the wet tube-like towel containing the seeds. Later, the students soaked the second paper towel with water, folded it, and placed it inside the bottom center of the cup to create a moisture wick.

After the lab, the class was introduced to photosynthesis and plant transpiration. Mrs. Jones used eating breakfast as an analogy for the body's source of energy. She described and physically demonstrated how students react when they do not eat breakfast. "Not eating causes a lack of energy. You become lethargic and drag throughout the day until you eat food for energy." Mrs. Jones began her explanation of photosynthesis by stating, "Plants also need food." She drew an illustration of two plants. The first illustration was a healthy plant that received sunlight, water, and carbon dioxide. The second illustration was an unhealthy plant that drooped, because the environment for growing the plant was different. Mrs. Jones reviewed the important role of the phloem and xylem to carry minerals and water through the roots to the plant stems. She explained how the stems separate the leaves to receive water, minerals, sunlight, and air:

> Photosynthesis takes place mostly in the plant leaves. Stomata located on the outer layer of the leaf tend to open with the sunlight and allow the water vapor, carbon dioxide, and oxygen to enter and exit the leaf. This is part of the process we discussed on the first day for combining water, minerals, carbon dioxide, and energy from the sun to convert into food for the plant.

Mrs. Jones wanted the labs to produce healthy plants like the one in her illustration.

Mrs. Jones ended her lecture by briefly describing plant transpiration as the plants' way of breathing and releasing water vapor into the atmosphere. Factors for growing plants such as temperature, humidity, and air circulation were important for the plant lab. Mrs. Jones stated, "As the seed transpires, the water wick will help to maintain a healthy moisture level."

Overall, Mrs. Jones' lesson on day two included two characteristics of teaching relevant to Zacharia and Barton's (2004) continuum. With this lesson, I observed both the TSS and the PSS models of instruction. The TSS model included her lecture, questions, and answers. The PSS approach included the lab experiment with the seeds aimed at helping students understand scientific concepts for plant growth. However, the activities seemed tightly scripted or controlled and did not seem to allow for much exploration. Therefore, I would not consider this a robust example of PSS. In the next session, I describe findings from the student journals.

Grade six student journals—day two. The same rating scale described above was used to rate student responses on what they learned. Eight students responded with examples. The number of examples ranged from average to low which indicated there was not a high level of engagement. Seven of the students expressed that they learned how to grow a plant without using soil and briefly mentioned plant transpiration. One student wrote a mixed review of the lesson. She wrote

> Compared to the first day's lesson, I didn't learn very much. We did a lab today and because of that we didn't learn very much. We planted lima beans in a cup. The point of the lab was so we could learn about the growth of plants while watching it happen in a cup. Today was [also] review from the last two days. I did learn about [things] that I had overlooked in my notes.

Five of the eight students responded with their ideas for constructive feedback. They stated, "the lab, review, and rewards made the unit interesting."

One student appeared to be more engaged than the other students and wrote the following:

> Planting the seed in the clear cup was pretty enjoyable but there are a few things we could have done to make this lesson more interesting. For starters, I think we could have used dirt instead of paper towels. I also think this lesson could have been more interactive. By this, I mean writing down a prediction about what we think will happen to each seed, [by planting] one upside down, [one] sideways and [one] right side up. I also think we could have decided how much water to put in the cup and how high or low we wanted to [place] the seed. I think this would be more interesting if we got to decide if we wanted a soaked lima bean. It would have been cool if at the end we could see [whose] seed grew the highest and what they did to make it grow that high. Also, the teacher is going to give a D-R slip to everyone at the table [whose] plant grows the highest. [I know that] it would be based on luck if the teacher did these things.

This example suggested the student had some interest in the lab, but she may have been more fully engaged if there were other options to increase her skills and experiences during the lab.

All participants expressed they wanted another lab and enjoyed working with plants. However, two students had mixed reviews which indicated their limited engagement in the lesson. One example is provided below:

> Altogether this lesson was enjoyable, but also kind of boring. Some people at my table were pretty bored because they didn’t get to do much. [The

> teacher] could have broken us into groups of twos or threes so everyone would have more of a chance to do something. I can't wait to see how much our plants grow or don't grow.

Another student's level of engagement was linked to the rewards given during the lesson reviews. She wrote, "I can't wait to do labs and more reviews [to earn D-R Slips and FOLs]."

Even though some of the students provided constructive feedback, their overall perspectives and engagement regarding the hands-on labs were lower than I expected. I thought the students would have more engagement and discussions comparing and contrasting their past and current experiences with the science unit.

Grade Six Observation Day Three

This intermittent observation took place three days after the lab with the seeds. Mrs. Jones included a lecture with handouts, a lab, and several opportunities for student discussions, questions, and answers. The smell of decomposing seeds filled the air. As a result, many of the students entered the classroom with complaints about the odor from their seedlings. Other students were curious to see their germinating seeds. With this in mind, Mrs. Jones asked students to check the center wick for moisture and add water if the wick was too dry.

Before Mrs. Jones introduced her second lab on plants, she briefly discussed the purpose of the xylem and the phloem. After this, she introduced the lab along with several handouts for completing a science lab report. The lab involved using celery stalks and dye to exam the xylem, the phloem, and pigment change in the leaves covering the stalks. Each of the students was given one celery stalk. Mrs. Jones asked the students to cut off the bottom of the celery stalk and place it in a mixture of blue food coloring and water. The students were directed to observe what happened to the celery and to pay special attention given to the xylem inside the stalk and the leaves growing on top of the plant. The students used two handouts to record their observations. The first handout entitled "Celery with a thirst for . . ." was used for hypothesis testing. The handout asked the following question: "Can water travel up a celery stalk?" Students wrote their hypothesis, along with two observations, and followed the procedures outlined on the handout. They also wrote the results and conclusion from their observations.

Mrs. Jones used a second handout entitled "The Scientific Method" to guide the students in writing their lab reports. The handout included the following categories and directions:

- Problem: What are you exploring?
- Hypothesis: Make an educated guess written in a complete sentence.
- Materials: List all materials used.
- Procedure: Step-by-step procedure that another person could easily follow.
- Results: Put the date and time that you begin your lab. Make charts, tables, graphs, or draw a labeled picture showing the results. Data observed during the experimentation must include all five senses (taste is only when told). Be very descriptive and thorough.

- Conclusion: Answer the problem that you wrote and tell if your hypothesis was correct or incorrect.

Mrs. Jones randomly selected six lab reports for my analysis. Four of the six reports were from student participants in this study. The student reports had not been graded, so I designed a rubric to examine and score the contents of the lab reports based on the *Science Lab Report Rubric* provided by the Utah Education Network as shown in Table 5. Each student wrote the same statement for the research problem, materials, and procedures. The students' hypothesis statements were clearly written. One student included the following hypothesis: "I think the celery will suck the colored water up through the xylem. I think the celery will change colors because the [chloroplast] will use it as a new pigment." Each of the lab reports was neatly written and included labeled illustrations of the celery talk and leaves.

My analysis of the lab reports indicated that the four participants, who were involved with this study, scored slightly higher than the students who were not participants. That having been said, all six lab reports contained good descriptions of the celery lab, and in my opinion, should have received a passing grade of A or B.

Table 5

Rubric for the Celery Lab Report

	Description	Point system
1	Lab description (problem, hypothesis, materials, procedure)	1 pt / each
2	Senses used beyond sight (hear, taste, touch, smell, intuition/impression)	1 pt / each
3	Quality of illustrations: Elaborate Details (ED) – 3 points Moderate Details (MD) – 2 points Basic Details (BD) – 1 point	1 – 3 pts
4	Labels used with illustration	1 pt / each
5	Hypothesis outcome	1 pt
6	Conclusion as a result of the test and experiment	1 pt.
7	Procedural instructions	1 pt / each
8	Use of the simple framework design in the handout	1 pt.
9	Use of other creative expressions	1 pt / each

In contrast to the seed lab, the class appeared to have more interest in the celery lab. The students could see immediate results in the celery lab. In the seed lab, it took several days to observe plants growing from seeds.

Grade six student journals—day three. The participants were asked to respond in their journals to the same three questions used for the observation on day two. See Appendix F. When asked what they learned for the day's lesson, the most notable learning occurred when the students: (a) examined the xylem inside the celery; (b) recognized the color change in the stained xylem; and (c) observed the color change in the leaves on the celery stalk.

There were two interesting comments from students who responded that they did not learn much from this lesson. Their comments suggest otherwise. One student wrote

> Today we got to see the xylem tubes we had been learning about in the past lessons. Though I didn't learn very much, it was cool to see the xylem tubes and how they sucked up the water from the cup. I got to touch and feel the xylem tubes. I didn't know they sucked up the water that fast, the whole xylem tubes were filled with water. I also found out that there can be more than one xylem tube in a plant. I thought I had read in our notes that there was only one xylem tube in each plant.

Another student wrote,

> I didn't really learn anything that much today. When we had to cut our celery, we saw the tube or xylem. I'm like WOW, that's amazing. My group's leaf turned brown, but when I looked around the class the leaves were blue, green, and all the rest of the colors that was neat. Now I know that can happen, I might want to try it myself and see what happens each day. I think that will be cool.

Even though the participation and interest levels of the students were high, two students wanted more information. One student wrote, "I wanted to see the xylem tubes through a microscope and observe the non-living cells." Another student wrote, "I wanted to answer more questions for the review and study notes. Instead of using one food color, the lesson would have been more fun if the students were given many different colors."

One participant thought part of the lesson was difficult. She did not have the confidence to receive a passing grade on her lab report. In spite of this, she noted her determination to try. She wrote, “We had to do the scientific method. It was kind of hard for me. I think I will get a bad grade for this. I’ll still try my best for it.”

Overall, eighty percent of the participants had favorable comments regarding the lesson with the celery lab. One student wrote,

> Today’s lesson was lots of fun . . . I think everyone liked this lesson . . . I have done stuff like this before, but I have never pulled out the xylem tubes to look at closely. Another student wrote, “I like today’s lesson. I didn’t know [that] I ate xylem until today. I hope we do more activities like this one. I told my mom about today’s lesson and she thought it sounded [like] fun.

The instruction with the celery included PSS instruction from Zacharia and Barton’s (2004) model. The lab, for example, reinforced students’ understanding of scientific concepts. Moreover, students had several opportunities to participate and see many immediate results using the food color and writing the lab reports to record their observations. Based on the student journal perspectives, their level of participation in the celery lab was significantly higher than at any other time during my observations.

Grade Six Observation Day Four

Mrs. Jones began day four with different seating arrangements that she created with her teaching assistant, Mrs. Davidson. Students were assigned seats based on their personality types. Some of the pairs were mixed gender and some were not. For example: Mrs. Jones and Mrs. Davidson seated the girls and boys they considered independent, ambitious learners in mixed gender pairs. Girls who were less aggressive were seated with girls who were more likely to work as a team and coach their teammates through the assignments. This pattern was similar for the boys. Boys who were playful during the labs were seated with students who were more engaged in the lesson. I observed some of the independent, ambitious students take over an entire lab from their passive lab partners. When the group of eager students was done with their experiments and reports, Mrs. Jones asked them to help other groups who were struggling with the assignment.

The seating arrangement contrasted slightly with the seating chart used earlier in this classroom. Of the nine table arrangements on day one, seven table assignments were single gender. One table had one male student (seated with Mrs. Davidson) and one table was mixed-gender. Also, on day one there were 32 students present: 15 female students and 17 male students. On day four there were 26 students present, 12 female students and 14 male students. Eight of the nine tables were used: five tables were single-gender and three tables were mixed-gender. One table had no seating assignment, because it was used to display the class experiments. The single gender table arrangements likely increased the probability that the passive students actively participated in the labs. From my observations in grade six, students seemed to prefer same gender seating arrangements. One of the participants confirmed my observation when she wrote the following statements in her journal:

> At the tables where there were a combination of girls and boys, the boys seemed to be doing most of the work with the hands-on stuff, while the girls would just take notes. At the tables where there were all girls it seemed to me that only one of the girls was doing the hands-on while the others watched. The tables with all boys seemed to me that all the boys would work together and stay on task.

After the seating assignments, Mrs. Jones discussed the visual results from the seeds growing in a cup. Many students complained again, about the unpleasant odor from the germinating seeds. Mrs. Jones stated, “The bad smell goes along with scientific experiments. Part of science [includes] trying experiments over and over again under different conditions.” Because some of the seeds did not sprout, the students were asked to observe their experiments and make a decision on the following three choices: (a) keep the same experiment; (b) clean their containers and plant the soaked seeds in the wet paper towels; and (c) use potting soil to experiment with planting either dry or soaked seeds.

Earlier in the week when two boys told their parents about their unsuccessful lab, their parents sent two large bags of potting soil to repeat the experiment. From my observations, the boys were anxious to repeat their lab under different conditions. While the girls were deciding whether they wanted to try another experiment, many of the boys were out of their seats measuring the potting soil for their next lab with the seeds. I became distracted from observing the girls’ participation when a male student asked me to look at his plants. He was proud to display the height of his team's plants. Another male student asked me if he had enough soil in his cup to redo the assignment.

Day four was the last day for students to record in their journals. During my observation a participant for the study asked me to explain the last day of questions. I briefly reviewed the journal prompts with this student participant.

Mrs. Jones brought closure to the lesson, by reminding the class to use their personal flash cards to review for the unit quiz. Earlier in the school year, she taught her students to make flash cards to study their notes and handouts. Next, Mrs. Jones reminded the students of Engineering Day and the rotations for grade six Pods. During this special occasion, prizes were rewarded for participation and competition. Students were also told to expect visitors. Next, Mrs. Jones asked the students participating in this study to complete writing in their journals. Although not all students completed their journals, the response rate for day four was likely to be higher than it would have been without Mrs. Jones' request. Lastly, Mrs. Jones asked the class to complete the color-coded worksheets from previous assignments.

Grade six student journals—day four. There were seven questions in the participants' journal for day four (see Appendix F). Cullingford (1993) completed a study on student views related to gender issues in school. He found that children were able to analyze their teacher's strengths, weaknesses, and "differential treatment to boys and girls" (p. 556). Items three, four, and five were designed to elicit the female students' perspective on gender equity in their science classroom. From the student perspectives, I wanted to know if the science unit was taught as equitably for both girls and boys, as well as explore the possibility that Mrs. Jones engaged in what the students viewed as exclusionary practices in teaching the unit on plants.

The students who expressed the most enjoyment were the participants who completed the two experiments. The following quotes were taken from two participant journals, “I mostly enjoyed when we changed our plants. I thought it was a bummer that our lima beans didn’t grow. I’m glad we got to plant them in soil.” The students thought the most interesting aspects of the unit included learning the parts of the plant and how they function, and Mrs. Jones’ examples. One student wrote, “Perhaps the most interesting thing I learned was photosynthesis. It was cool to learn how plants make their food and I really enjoyed it. I never knew how complicated it was for plants to make their food and it only takes water, air, carbon dioxide, and sunlight.” Another student wrote, “I liked learning about the stems and roots and I liked when Mrs. Jones did the example.”

Six of the seven respondents indicated that both girls and boys enjoyed the unit. One student wrote in her journal

> I think this science unit was attractive to both the girls and the boys for the same and different reasons. Both the girls and the boys liked the hands-on things we did. I think the girls liked doing the xylem tube thing we did while the boys like planting the seeds.

Two of the participants stated the girls enjoyed the unit more than the boys, but their statements did not include a specific reason explaining their claims, which suggests that the question might have been leading and they were simply agreeing. This interpretation is supported by one participants' response, "I think that the girls enjoyed this science unit the most. The fact that Mrs. Jones was excited and put energy to make the science unit interesting and fun made both girls and boys enjoy this unit."

When asked what made the unit attractive to boys, the participants commented that the boys were not as engaged in the science unit as the girls. More specifically, the boys were not seriously engaged in the paper-pencil assignments such as writing lab reports. One participant stated the boys were more engaged in activities where they could receive rewards: "I think the science unit was attractive to the boy[s] because of the D-R Slips and the FOLs and maybe because of the grades they are getting in science."

The girls' responses also indicated that they were influenced to some degree by the special attention they received from participating in the study. For example, one student wrote: "I think the girls like the science unit because we got to act a little bit more than the boys and maybe because of the science experiments." Likewise, another student wrote: "I think it [was] made attractive because when you gave us our journal we got to express our feelings [about the unit] and [got the chance to] say what we wanted in the journal."

Six of the ten students continued to express confidence that they would receive a passing grade on the unit. One participant stated

> I still plan to get an 'A' on this science unit. During the one lab we did, I made sure that I described what happened in detail and I drew nice

> clear[ly]-labeled pictures. I used my scientific method sheet to help me. On this lab, I hope to earn an ‘A.’ During this whole lesson, I have been paying attention to the teacher and taking accurate notes. I am making flash cards to help me study for the test, which is probably going to make up most of my grade for this science unit.

Even though another participant was less confident, she expected to receive a passing grade. She stated, “I expect to earn an A, B, or a C because I’m not so good in science.”

I observed two prominent themes in the responses to why the participants felt they would earn a passing grade. Many of the girls reported that they: (a) paid attention and (b) worked hard. One girl wrote: “I did all the work on time, paid attention during class and I’m hoping to do well on the test.” Likewise the participant who seemed less confident about her grade noted: “I didn’t try hard enough and I also think science isn’t the thing for me. I’m not good at it. And I don’t think I will be good at it.”

Grade Six Post-Observation Interview—Mrs. Jones

I reviewed the students’ journal responses with Mrs. Jones. We began our review by briefly discussing the relationship between culture, disability, and science education in the context of the performance of one student who was American Indian. While Mrs. Jones’ lab on plants was interesting for most students, the journal responses from an American Indian student were incomplete. Based on a discussion we had in the WISE Investments program, I suggested that one possible explanation for the incomplete lab was that working with bean plants before the child was properly initiated by her tribe may have violated her cultural practices. Mrs. Jones acknowledged that this may be the case and expressed an interest learning more about the student's culture. This same student was enrolled in the special education program, which might also explain why she did not complete her journal. Mrs. Jones and I tried to offer the student assistance but, according to Mrs. Jones other students from the same tribal nation also did not respond to the extra attention. Likewise, the student and I made plans to meet during lunch but she avoided the meeting. Mrs. Jones decided to contact the counselor for more information on how to work with the student and her family.

We also discussed a second incomplete journal from a participant whose achievement was very low. This student did not qualify for special education services and there were no school policies in place to address this unique circumstance. Although Mrs. Jones wanted to modify the student's assignments to insure successful completion of all science units, she was concerned about the legal aspects of modifying the curriculum.

We continued the interview by discussing the results from the other eight journals. All of the participants enjoyed the plant and celery labs. One student wrote that she would have preferred looking at the xylem and the phloem under a microscope. She wanted to see the difference between living cells and non-living cells. Mrs. Jones said under normal circumstances she used the microscopes with her demonstrations. She typically brings in another plant for a lab in which her students place nail polish on the leaves and peel off the film to see the chloroplast. It was too late to add this lesson with a different plant, because Mrs. Jones was scheduled to teach a unit on the water cycle and host Engineering Day for all of the grade six pods. “I regret that I did not add the lab with the chloroplast. It’s kind of unfortunate that I do not have the time.” Mrs. Jones valued this information from the journals and the constructive feedback she received from her students. She stated, “I love this feedback. This is great!”

In another journal, a student mentioned that some of the girls did not get a chance to participate in the hands-on labs. I asked Mrs. Jones if she considered assigning student roles during the labs.

> No, because I did that in elementary school and I figured that by middle school the students would all participate. Maybe I need to go back to assign[ing] more roles. There is always the dominant personality that wants to take over and do everything.

Interestingly Mrs. Jones attributed this comment to personality rather than gender dynamics, suggesting that the problem is individual group dynamics and not gender inequality in classroom dynamics, a more systemic issue.

We initially discussed using the next day to work with students who needed extra time for completing their assignments. Instead, Mrs. Jones decided that she wanted all of her students present for her special presentation. “I am showing my Rat Playing Basketball video tapes. When I was in the sixth grade, my science project was to train rats to play basketball using positive reinforcement.” Mrs. Jones posted the newspaper article that captured her own sixth grade science project on the wall near her desk. This newspaper article depicted her first place award and her sixth grade science project. She used this special presentation as one tool to motivate her students. When she was in school, students were not allowed to bring in live animals. The school would only permit her to film each stage of her rat, “Yogi,” with the basketball. Mrs. Jones also used her special presentation to model how to present a science project.

> The way that I came about the science project was going to CO-SCI. It is a hands-on science center in Columbus, Ohio. I told my dad that I wanted to do that for my science project. The employees at the center said, ‘*only scientists have done this.’* My dad had a man come to our home with the information that I needed. I had to do further research and build the actual basketball court out of Plexiglas. A man with the nickname, Yogi helped me. That’s why I named my rat, Yogi. The entire project took about nine months. I entered it in two different science fairs. I won the one at my school and I came in first place at the state science fair. Not only did my dad support this project, he also helped me to get my amateur radio license. He exposed us (two girls) to many things that made us like science. My sister’s science project was on artificial intelligence with the Apple IIE.

After Mrs. Jones reminisced about her personal middle school science project in grade six, we discussed her level of satisfaction with teaching the unit on plants.

> I think highlighting the notes went well. Typed notes really work well with this age group. Asking them to write is too much. They could write it wrong, which could lead to misinformation. My labs [also] went really well. I like the fact that we [had time] to replant seeds. At first, I was

> frustrated with my seeds, but then hearing the feedback [from] the kids on how they enjoyed replanting, helped me change my frustration. The students who brought the potting soil wanted to plant more. So, I am going to re-pot their plants into bigger pots and bring them in. That makes me feel good.

Mrs. Jones preferred tables in her classroom instead of student desks. She changed the students' seating, because it gave the class a chance to work with different groups. Interestingly, she too believed that students at this age were more comfortable when they worked within same gender groups. Her ideal setup was tables with two girls and two boys, but this was not always possible because of the dominant personality types.

Mrs. Jones' enthusiasm was an indication that she enjoyed teaching sixth grade science. Her greatest inspiration for teaching science in grade six came from her dad's encouragement to pursue her personal interest and actually work with a scientist during her school science project in grade six. The participants expressed pleasure in listening to Mrs. Jones' stories and the hands-on labs. The participants also enjoyed the rewards used in the lesson reviews to recall basic information. Mrs. Jones used the rewards as one strategy to encourage her students' participation.

Mrs. Jones was eager to receive the feedback from the participants' journals. She made plans to log the suggestions in her calendar to use microscopes and the variations of dye colors in the labs for the next school year. Mrs. Jones expressed that she wanted to enhance her instructional strategies with these tools to help students understand key scientific concepts in the unit.

Based on Zacharia and Barton's (2004) continuum for a "defined science," the grade six participants' perspectives toward science were shaped largely around instruction in both the TSS and to a much lesser extent, the PSS models. There was no evidence that Mrs. Jones engaged in the CSS model that incorporates local, community, and personal science projects in the classroom.

Grade Six Focus Groups

Fifteen parents and students were invited to participate in the focus groups. Mrs. Jones, the sixth grade science teacher, encouraged her female students and their parents to participate in the focus groups by calling their homes with reminders. In addition, she stood at the school's entry to greet the parents and her students when they arrived for the focus groups. I conducted separate focus groups with six parents and eight student participants. The focus groups were designed to explore the parents' and the students' perspectives regarding the girls' interests in science at home, in the community and at school, along with the parents' encouragement for success and their daughters' interests in careers.

The intent of the parents' focus group was to identify activities the parents used to support their children as well as survey their children's interests in science that was not required homework. I used the same 15 semi-structured questions for both focused groups. The focus group protocol also included questions that asked parents and students to rate their interests and satisfaction in science education on a five-point scale. A copy of the protocols for the focus groups can be found in Appendix B and Appendix C.

Grade six parents' focus group. Most of the parents reported their daughters' interest and participation in science was above average in all three domains: school, home, and community. Examples of science participation at home included environmental projects, routine house chores such as maintaining the landscape, painting, cleaning; animal care; experiments using household chemicals; constructing dinosaurs; projects at the science center such as building a solar car, and launching rockets.

In general, the parents expressed satisfaction with their daughters' participation in school science. One parent stated, "The [science] curriculum here seems a little more advanced and a little more interesting." When I asked the parents about their dissatisfaction with the science curriculum, one parent stated, "[Our children] need to be able to see the application in their future." Another parent responded, "[My daughter] has had some of this [science] curriculum, so some of it is a review." In relationship to culture, religion, and gender, the parents placed no limitations on learning science. To understand key scientific concepts, they believed it was important for their daughters to experience hands-on activities in all aspects of science. All parents strongly encouraged and supported their daughters' participation in science through activities such as family membership at the science center, museum, ongoing discussions about the human body and health, visits to the National Parks and conducting experiments at home.

When asked about the parents' science related careers, one mother in our group was a physical therapist. The other participants stated their husbands were employed in careers such as a doctor, chemist, pilot, and engineer. Three of the participants stated their daughters expressed above average interest in their mothers' careers and four of the participants stated their daughters expressed above average interest in their father's careers. Two parents stated their daughters had above average interests in both parents' careers. Two participants expressed low self-confidence in their own engagement with science such as, "Mom does not do anything science related other than cooking." Another parent stated, "Her dad is much stronger and able to help with science. I am [a] very strong encourager and supporter."

The parents stated their daughters had interests in science related careers such as the medical professions, aviation, veterinary medicine, and cancer research. One parent stated her daughter would do well in a career as a doctor because, "She does well in her school work and she is sympathetic to the needs of people." However, the majority of the parents also believed that their daughters would excel in careers that were not related to science such as teaching, marketing, musical entertainment, drawing, and writing.

Grade six girls' focus group. Six of the eight girls stated they had above average interest in learning science at home, in the community, and at school. Examples of the girls' use of science at home included mixing liquids, growing plants, working on the lawn, and using electricity. The participants discussed science in the community in relationship to outdoors, natural phenomena, and family visits to museums. Six of the students also expressed above average interest in learning science at school through topics such as the solar system, the human body, plants, and using experiments to mix chemicals.

All of the participants in the focus group expressed above average satisfaction with their science education. Four of the participants were satisfied with their teacher and three of the respondents expressed satisfaction with the hands on activities such as experiments in labs and projects. One student expressed dissatisfaction with "just reading and taking notes."

When asked about their parents' encouragement in science education all of the respondents reported that both parents helped with science homework. One student stated, "My mom loves science so she likes to help me with my science work." Four of the participants stated their fathers helped with their science homework. One participant stated, "If I have a science project due, my dad will help me research for it. [He] takes me to the library and helps me with the [I]nternet."

Six of the participants stated they had expressed to their parents an interest in science and related careers. Some of their career choices included science teacher, astronom[er], fire fighter, physical therapist (for athletes), family physician, veterinarian, and cancer research. The participants also thought they would do well in careers related to entertainment, coaching, and cosmetology. Only two of the girls indicated an above average interest in their mothers' careers while six of the girls were interested in their fathers' careers. In the section that follows are my observations from the grade seven teacher interviews, science classroom observations, student journals, and focus groups.

Grade Seven Science Instruction

At the time of this study, Mr. Clarke, the seventh grade science teacher had been teaching science for five years and enjoyed teaching geology and plate tectonics. In the pre-observation interview he explained that his favorite unit covered geological time. Mr. Clarke felt it was important for students to question and study different perspectives about past events and the age of the earth. In his experience, his students had "fascinating discussions" related to the age of the earth and common theories explaining the rise of man. Mr. Clarke explained

> All of their questions have so many answers, but all these answers are theories. The presence of multiple theories allows students to examine their own ideas and form new beliefs. In addition to this, geological time covers another captivating subject for students –dinosaurs.

When I asked Mr. Clarke if there were staff members at Riverside Middle School who mentored him for teaching seventh grade science, he hesitated in his response

> If I were to choose one staff member to call a science mentor, it would be Mrs. Anderson. She is currently teaching grade six science, but has taught science over the past ten years in all three middle school grade levels. She is exceptional at both planning and implementing interesting educational activities. She is also the staff member on the forefront of integrating technology into her science classroom instruction.

Mr. Clarke described the following teaching strategies that he used to encourage student participation:

1. asking essential questions;
2. taking knowledge learned in class and responding to questions that solicit higher order thinking; and
3. physical involvement using gross motor skills is included in teaching ideas to reinforce retrieval of information.

During the interview, Mr. Clarke had a list of community members that were available to support his science curriculum such as parent experts, mentors from the local university, employees from a high profile software company, and staff from the local science museum and the rock museum. However, Mr. Clarke did not describe any specific talent the stakeholders provided or how he incorporated the experts and resources into his science instruction. He thought one barrier to the use of local community resources was “time to plan meaningful field trips.” Later in our conversation he described the district’s science coordinator as an additional resource, because she provided curriculum guides aligned to the state standards, science kits, and suggestions for implementation. The science kits were available for check out and the school’s computer lab was available time for science lessons and related inquiry.

When asked about girls’ achievement in science, Mr. Clarke cited a pattern he noted in his grading. He found on average, the female students in his classes scored approximately two or more percentage points higher than the male students. According to Mr. Clarke, middle school girls outperform middle school boys, because the girls completed the required assignments more often than the boys. Mr. Clarke also observed that students –girls or boys-- who were very successful in math were also very successful in his science class. Even though Mr. Clarke had no specific training related to female achievement in science classrooms, based on what he characterized as his personal observations, he believed the only barrier to the girls' achievement in science was that science was considered male-dominated.

> To dispel this belief, there should be more strong science teachers who are female. Moreover, a professional development course should be offered to middle school teachers with expertly designed activities that are directly aligned to the state standards. To encourage more participation from female students, this professional course should include daily activities for science demonstrations and sample lesson plans.

However, this latter suggestion was very general and Mr. Clarke did not explain how the professional course he described would specifically address increasing girls' engagement and interest in science.

During my classroom observations, Mr. Clarke taught his favorite unit in geology with the different theories related to geologic time over a two-week period. As in the sixth grade classroom, the six female student participants in grade seven recorded their thoughts and feelings about their instructional units using individual science journals. The participants recorded their perspectives on four of the 15 days of my observations.

Grade Seven Observation Day One

Mr. Clarke's unit was largely, if not exclusively aligned with the Traditional School Science (TSS) model of instruction (Zacharia & Barton, 2004) that addresses school science through lectures and "explanations of natural phenomena" (p. 203). As described earlier, this method of teaching science provides an objective view of the world and positions students as only receivers of information. Mr. Clarke's lesson was comprised of a series of lectures and note-taking. With the exception of a short demonstration using props, Mr. Clarke provided students with few opportunities to participate in the lecture or ask related questions. He began his introduction to plate tectonics with a lecture entitled "Earth's Drifting Continent." He used the overhead projector to display a figure depicting earth as a single continent as he discussed the theory that the earth was once a single land mass known as Pangaea or earth's super-continent.

Mr. Clarke explained that this single continent existed approximately 200 million years ago. Students were asked to take their first notes from the information he presented on the overhead screen about Alfred Wegener, the German geologist and meteorologist. According to Mr. Clarke, in 1915 Wegener had evidence to support the theory explaining continental drift, which included sea floor spreading, mid-ocean ridges, and plate tectonics. He explained that Wegener's evidence was comprised of fossils located on different continents as we know them today, such as South America, Africa, Australia and Antarctica. These fossils contain the same or similar animal and plant remains. Mr. Clarke used the world map on the rear wall to identify the continents and countries such as Brazil and South Africa, with similar plants, rock formations, and coal fields.

Next Mr. Clarke demonstrated sea floor spreading and mid-ocean ridges with two large rolls of brown and green butcher paper. At his request, one student laid her head on her desk while the teacher rolled the brown butcher paper to cover her. A second student seated next to her was asked to do the same as the teacher rolled the green paper to cover her. According to Mr. Clarke, the brown and green paper illustrated sea floor spreading and the two students under the paper demonstrated the mid-ocean ridges.

Mr. Clarke described mid-ocean ridges as underwater mountain ranges that create boundaries between two plates. Sea floor spreading is the movement of the oceanic plates away from each other. When the plates move apart, a weakness is created in the ocean floor and magma is exposed from deep within the earth's mantle located between the core and the crust. The volcanic action releases lava and creates new ocean crust and ridges.

Mr. Clarke ended the first day of the unit with a lecture that outlined the theory of plate tectonics discovered in the 1960s. This theory described the movement of earth's crust with the eight major plates and smaller oceanic plates. The major plates are our modern day continents plus one land mass and one ocean mass: Africa, Antarctica, Australia, Eurasia, North America, South America, India, and the Pacific Plate. Divergent plate movement occurs with sea floor spreading when plates move apart. Convergent plate movements occur when two plates collide. The two plates can be either continental plates or oceanic plates.

Mr. Clarke closed his lecture with a brief discussion explaining that subduction occurs when one convergent plate slides under the other, melting it into the earth's mantle. Shortly before the class period ended, the students were asked to complete taking the class notes from the board.

Grade seven student journals—day one. Because Mr. Clarke's lesson was very teacher-centered with minimal student participation, it is not surprising that the girls' journal responses suggest a low level of engagement with the material. For example, in the question asking the girls to describe what they learned, all six girls restated relatively basic information that Mr. Clarke covered in his lecture such as in the following comment:

> I learned a lot about the theory of plate tectonics, that Alfred guy, and sea floor spreading. Also, I learned about mid-ocean ridges and Alfred's land puzzle.

None of the students' responses explained key concepts or the relationship between plate tectonics and sea floor spreading which would indicate a deeper engagement with the material. One student expressed that she had previous exposure to the information Mr. Clarke presented by noting, "Last year we studied the ocean so some of the stuff was familiar." The other five students reported that they knew nothing about the topic. Likewise, none of the girls had any suggestions for anything to add to the lesson. Although four of the participants thought the lesson was interesting, they did not identify or comment on the part of the lesson they found interesting. One student added, "[Mr. Clarke] is a great teacher," but she did not explain what made Mr. Clarke or his lesson great.

The students' comments suggested that their engagement with the lesson was low because they did not discuss information beyond the level of recall. Even though the students appeared to be focused on the lecture and the class demonstrations, from my perspective they were more interested in taking notes to study for and do well on the unit exam. The entire class was highly engaged in taking notes. As stated earlier, Mr. Clarke taught from a traditional model of science, where science concepts are taught for test competence. Based on the student journals and my observations inside and outside the classroom, students were interested in Mr. Clarke as their teacher. The students thought Mr. Clarke was a great teacher because as the wrestling coach, he was one of the most popular teachers on campus.

While the girls' journal responses suggested they came away from the lesson with a rather superficial knowledge of the topic, five of the six girls reported that they expected to earn an "A" grade or higher on this unit. All of the girls reported that they would do well in the class by following the teacher's directions. For example one student stated: "I plan to earn this grade by paying attention in class and completing and turning in all of my assignments."

Grade Seven Observation Day Two

Mr. Clarke continued to lecture on the continental and oceanic plates. There was one class activity that required students to copy information from the white board, but there were no student discussions or time spent on students' questions and answers. Mr. Clarke reviewed material from the first day, distributed a handout entitled *Seeing Inside the Earth: Earth's Layers*, and discussed the movement between the layers of the earth.

Mr. Clarke discussed continental drift and used the handout to lecture on the layers of the earth and plate boundaries. He drew and explained the four major layers of the earth on the white board: crust, mantle, outer core, and inner core. After this, Mr. Clarke asked the class to draw and label in their notes the four major parts of the earth. Using wait time in the class for students to complete their illustrations, he continued to lecture.

> The crust is the part of the earth that we live on which is made up of hard solid rock. The crust is also the coolest part of the earth. The deeper we go into the earth, the warmer the temperatures. Underneath the crust is the mantle, which is very hot. Below the mantle, is the outer core which researchers believe is liquid metal. The outer core is much hotter than the mantle located above it. Below the outer core, is the inner core. The inner core consists of solid metal which is extremely hot.

After the discussion of the major parts of the earth, Mr. Clarke explained the handout describing the lithosphere and the asthenosphere. The lithosphere was defined as the "rigid" part of earth that consists of the lower part of the earth's crust and the upper portion of the mantle.

> This part of the earth is made of both continental plates and ocean plates that move. Beneath the lithosphere is the asthenosphere. The

asthenosphere consists of the lower portion of the mantle and is partially molten, like soft plastic.

Mr. Clarke reviewed the theory of plate tectonics by stating that there is always some movement or shifting of plates in the earth.

Some plates move apart (divergent plate movement) while other plates move together or slide past each other (convergent plate movement). Scientists believed that there are hot currents beneath the lithosphere in the deeper part of the mantle which cause the plates to move. When plates move apart, they create a gap where magma or hot molten rock rises and cools.

Mr. Clarke reminded the class that this process is known as mid-oceanic ridges which form valleys and mountains.

From this movement, a new lithosphere is formed at the divergent boundaries where the plates move apart. When the older lithosphere collides and melts away as it is moved underneath a continental plate, subduction occurs. The oceanic plate melts in the hotter part of the mantle forming magma. When this happens the process creates volcanoes and later mountains are formed.

According to Mr. Clarke, "scientists also believe that some plates move horizontally causing large cracks in the earth which result in fault boundaries." He ended the lecture by stating that "fault boundaries create earthquakes", the topic of his next lecture.

With the absence of interactive student activities and items for student discussions, Mr. Clarke's lectures provided one-way communication. The students listened to the lecture and followed simple directions. They were passive receivers of information. The findings from my analysis of the journals are consistent with my analysis of the observations. Again, Mr. Clarke's teacher-centered approach to learning followed the structure of the TSS model.

Grade seven student journals—day two. The participants' journal perspectives indicated a very low level of engagement. One student reported that she did not remember anything. When asked how the lesson could have been more interesting, two students stated the lesson was interesting, without any further explanation. Another student wrote the lesson would have been interesting to her if, "We could have talked more about the notes." When students were prompted to write additional thoughts and comments, only one student added a thought about the science unit which indicated recall information from the lecture. She wrote, "I learned that there is evidence that South America and Africa could have been connected." This same statement was used to respond to another response in her journal. Overall, the participants repeated recall information and commented about taking notes. For example, one student stated: "We took notes and I learned about rifts, sea floor spreading, and subduction."

The sparse responses in the journals could also be attributed to the limited amount of time the participants had to write. I observed that on most occasions, the participants did not record their ideas immediately following the lecture. After Mr. Clarke finished his lecture, all of the students in this class were busy trying to complete the teacher's assignments for the day or preparing for their next class. My presence did not seem to remind the participants to write a few notes in their journals after the lecture. Near the end of the class period, Mr. Clarke gave me a few minutes with the participants in the hallway to discuss their journals. I offered a suggestion to leave the journals with Mr. Clarke so he would remind the participants to complete them after the lectures. Five of the participants preferred to write in their journals after school or at home.

Grade Seven Observation Day Three

Similar to the first two days of my observations, the lesson Mr. Clarke presented on day three conformed closely to the TSS model of teaching science. In this lesson, I observed what I would describe as a slightly higher level of student engagement compared to the first two days. This slightly higher level of engagement could be attributed to the brief classroom activity.

Mr. Clarke began by illustrating an earthquake and the seismic waves caused by the release of energy in an earthquake on the whiteboard. In the first illustration he drew a cubed outline of the earth exposing two layers: the continental crust and the mantle. Next Mr. Clarke described a fault as a crack in the earth that is created with movement between plates. He explained: "the plates scrape horizontally or vertically passing the other." Each student was asked to demonstrate the plate movement by placing their two hands together with the thumbs folded under the index fingers. With the two index fingers rubbing horizontally passing the other, the students slightly moved their left hand toward them while moving the right hand in the opposite direction.

When the horizontal demonstrations were completed, Mr. Clarke drew two cubed outlines of the earth. The cubes were drawn side by side to shift vertically in opposite directions. The point where the cubes scraped past each other was another description of a fault. Mr. Clarke stated, “Earthquakes usually occur along a fault when there is vertical movement in the earth.” On the white board, he drew small and progressively larger circles around the cubes to illustrate the vibration or energy released from the shift. The shift is also known as the focus, between the plates.

> The release of energy is what we feel in an earthquake. The waves from the focus are known as seismic waves and can travel deep below the surface. The epicenter is the area directly above the focus.

Mr. Clarke briefly described terms related to earthquakes such as seismology, seismographs, and the Richter scale.

> Seismology is the study of earthquakes and seismic waves. The people who study earthquakes are seismologists. They use a sensitive machine called a seismograph to record the earth’s movement.

He showed the students a picture of a seismograph using the projector and illustrated two types of seismic waves on the white board. The faster P wave or primary wave was modeled as a lengthwise small spring motion. The slower S wave or secondary wave was modeled like the shape of a large snake moving in slow motion. Another example Mr. Clarke used to explain the shape of the S wave was a loosely suspended rope. Mr. Clarke proceeded to discuss the earthquakes’ intensity.

> The Richter scale measures the magnitude or extent of damage from the seismic waves. For example, a magnitude of 3.0 may not be felt by most people, but it is recorded frequently (more than 100,000 times) each year. A magnitude of 7.0 causes serious damage and may be recorded at least ten times per year.

After the lecture, the class completed a handout on the epicenter, Richter magnitude, definitions, and study questions. Mr. Clarke gave the class time to complete the handout using their notes. After a few minutes, he read the questions and gave the students the correct answers.

This assignment was designed for students to recall information which is consistent with the TSS model. The handout included fill-in-the-blank, true and false, and short answer questions. The questions were not designed to incorporate higher order thinking skills using a level of analysis, synthesis, and evaluation of material. Below, I analyze the students' journals, focusing on engagement and understanding.

Grade seven student journals—day three. As indicated by the participants' journals, the students' level of engagement did not show much improvement. When asked what they learned, one student wrote recall information. She stated, "I learned about earthquakes and volcanoes, and how magma moves the land plates. And I learned how islands were formed." The remaining five students wrote about the assignments they completed. For example, one student wrote, "[We] [t]ook notes. We drew what we thought the earth looked like." Similar to the responses about the earlier lessons I observed, three students thought the lesson was interesting, but they did not state how the lesson was interesting. In the last prompt that requested additional thoughts, one student restated information about their illustrations of the earth, “We drew pictures of what we thought was inside the earth and I had crust, mantle, core, and then a layer of absolutely nothing!”

Grade Seven Observation Day Four

On the last day of the unit, Mr. Clarke offered many opportunities for students to participate and understand scientific concepts by using class demonstrations, handouts, and virtual earthquakes to engage his students. Mr. Clarke scheduled class time in the school’s computer lab to explore virtual earthquakes and use geological labs online: www.sciencecourseware.com/virtualearthquake. This virtual lab was made available by California State University at Los Angeles through a project supported in part by the National Science Foundation and was aimed at helping students understand the epicenter, the Richter Magnitude, and other concepts related to earthquakes.

The class also completed two handouts. One handout had nine items on *Intensity and Magnitude*. The last assignment was entitled, *Let’s Have an Earthquake*. The students followed directions from the handout to practice finding virtual fault boundaries and recording virtual earthquakes.

There were 33 computer stations in the lab. Students were asked to find a partner and work in groups of two. Many of the students waited for the lab technician to assign them a computer station. Some students worked alone. Two boys ran to a station so they could work together. The two boys seemed to be excited about using the computers and also seemed to have the most experience using computers. For example they helped other students go online and assisted with individual problems using the website. I, too, became a participant observer as I helped to explain the assignments and assist students who had problems finding the website. When the class was settled, Mr. Clarke reviewed the day's assignments.

Mr. Clarke used the white board to draw circles illustrating seismic waves containing both biangular locations and triangular locations. He discussed seismograph measures for P waves and S waves. Mr. Clarke demonstrated the impact of the waves by lifting a student seated in a chair. Holding onto the chair, the student received a quick jolt during the first lift to symbolize the faster P wave. During the second lift, symbolic of the slower S wave, the student almost fell to the floor, indicating the greatest impact. Mr. Clarke completed the first handout with the class. The class was actively engaged in using the computers to predict locations for earthquakes, finding earthquakes, and recording the magnitude.

Unlike his prior lessons that were consistent with the TSS model, Mr. Clarke's instruction in the computer lab was closer to what Zacharia and Barton (2004) described as Progressive School Science (PSS). In PSS, the use of technology offers "multiple opportunities for students to 'work with' scientific ideas" (p. 201) and expand their conceptual understandings of natural phenomena. The students' journal perspectives reflected a slightly higher level of engagement which is likely attributable to the activity using virtual labs to understand earthquakes, which all of the students seemed to enjoy.

Grade seven student journals—day four. When asked what they enjoyed learning, all of the participants suggested they enjoyed learning about earthquakes and volcanoes. One student wrote a few details about what she learned, but her response did not suggest that the lesson engaged her critical thinking skills. She wrote

> We talked about earthquakes on this day and what makes them. An earthquake is the shaking at the earth caused by sudden moves in the crust. We were also taught about P-waves, S-waves, and L-waves. Did you know that since L-waves are the slowest kind of earthquake waves, they are the most damaging?

One explanation for why this student's response did not include critical thinking skills, is that up to this point Mr. Clarke used patterns from the traditional model for teaching science which is structured for students to listen to lectures, take notes, and memorize key ideas "to be mastered for tests" (p.203). This student repeated information from the handouts which was going to be included on the unit exam. The participants' responses would likely have reflected more evidence of higher order thinking if Mr. Clarke had included more discussions involving analysis, synthesis, or evaluation of the scientific concepts. In contrast to the TSS and PSS frameworks used by Mr. Clarke, the CSS approach to teaching requires higher order thinking along with key scientific concepts that involved in everyday life (Zacharia & Barton, 2004). For example, scientific case studies could be used to engage students in teamwork to analyze, predict, create, design, apply, and evaluate situations using science in their communities. Later during the post-observation interview, Mr. Clarke expressed his need for a mentor to assist him in designing lessons to "include higher order thinking skills with engaging student activities," even though he also considered the time to create and provide such activities a barrier to implementing these lessons.

Overall, the responses in the journals suggested a high level of student interests and participation in the virtual labs. When asked what they enjoyed about the unit, one student enjoyed working independently, but stated she did not learn much from the unit. Three students enjoyed the activities in this science unit. One student that she enjoyed the teacher's demonstrations related to the science concepts without providing any additional details. Another student did not respond to the prompt, but wrote a general statement on how much she was intrigued with science and natural phenomena.

> Science fascinates me. I always want to learn more and wonder at many things. I wish to someday be able to answer many of my questions with my own skill and research. I think part of the reason I like science so much is that you can never finish it.

I expected most of the participants to discuss the virtual science labs in depth, but no one commented on the lab or the other assignments used in the computer lab. Similar to grade six, the participants in grade seven enjoyed participating in the science activities.

In response to who enjoyed the science unit the most, the girls or boys, the students stated that "both the girls and the boys enjoyed this science unit." In two follow up questions the participants stated, "There was no distinct attraction for boys" and there was no specific attraction for girls. One student wrote

> This science [unit] was attractive to both boys and girls because [the teacher] tried his very best to make this unit very interesting for the whole class not just the boys or not just the girls.

According to these perspectives Mr. Clarke's instruction did not include any favorable or unfavorable content for either gender. My observations along with the responses to this question, suggest that both girls and boys expressed similar levels of interests in the assignments. Therefore, both the instructional strategies and level of student participation could be considered gender equitable. Overall the seventh grade science lesson was teacher-centered. As a result, it might be described as gender equitable in its lack of student engagement.

From my perspective, the curriculum content was male-dominated in the sense that Mr. Clarke only cited the male geologist Alfred Wegener and his theory of Pangaea (earth as one super-continent). Mr. Clarke did not mention any female seismologists or geologists. For example in 1936, a female seismologist, Inge Lehmann discovered that the earth's liquid core had a solid inner core (Yount, 1999). Also, in the 1950s Marie Tharp, a female geologist worked with a male colleague for mapping mid-ocean ridges (Frolich & Davis, 2002). Enriching the curriculum with discussions of relevant female scientists is a strategy that Mr.

Clarke could have used to add inspiration, interests, and exploration for both girls and boys.

I compared the girls' confidence in their unit grades before the science unit to the grades the girls anticipated at the end of the science unit. One student had changed her prediction from an "A" grade to a "B" grade and two students had no response. This may suggest that their level of confidence had changed after the unit was taught. The other students' responses indicated a positive association with their level of confidence for earning an "A" grade –they followed the rules and as a result, expected to receive A's. During class these students listened closely to the lectures, understood the instruction, completed homework, turned in all assignments, and worked very hard to get the correct answers on their unit assessments. One student provided an additional thought. She stated, "I think I did very well and I want to thank you [the researcher] for putting up with this journal being so late. Thanks. It's been fun!" I interpreted this statement to mean that (a) the student enjoyed the extra attention from writing in the journal and participating in the study; or perhaps, (b) this student thought that participating in the study would improve her grade. This student expected to earn an A+ because of her study habits.

Initially, I anticipated observing many hands-on activities throughout the grade seven science unit instead of lectures from Mr. Clarke. Hands-on activities are considered best practices in science education. Students learn best in science classrooms when they collaborate with each other and use hands-on activities in labs (Donovan & Bransford, 2005; Zemelman, Daniels, & Hyde, 1993). Also, I expected to observe a few students acting out during Mr. Clarke's lectures, which might indicate that the students were bored, but all of his students appeared to be attentive, even though lectures were Mr. Clarke's least favorite teaching strategy.

Mr. Clarke's perspectives about teaching science (as he expressed in the pre-observation interview) were somewhat inconsistent with what I observed in his classroom. For example, in the pre-observation interview, he identified three strategies that he used to encourage not only girls' participation, but all of his students to participate in class (a) utilizing essential questions; (b) including knowledge from class instruction to develop higher order thinking skills; and (c) physical involvement using gross motor skills. During my three weeks of observations, I did not observe Mr. Clarke using essential questions or questions from the lectures to develop higher order thinking skills. Mr. Clarke used gross motor skills in very short activities to demonstrate conceptual understanding in sea floor spreading, plate movement, and seismic waves following earthquakes. In the first demonstration, only three students were involved as "props" to support the illustration, which was a fairly passive use of gross motor skills. In the second demonstration the entire class participated in this concept by touching and moving their right hand horizontally passing the left hand. While all students were engaged in movement, they imitated Mr. Clarke's example. In the last demonstration, only one student used gross motor skills to illustrate the jolt of seismic waves. During the first and last examples, the other students in class were simply passive observers.

In most cases, the students' journal responses were briefly written. There was no depth to their engagement with the material presented in class. From the lectures, Mr. Clarke did not use hands-on activities or labs to increase class participation and understanding with the information. One participant's journal response indicated a natural curiosity about science. She stated that she "had many questions" but, she did not provide examples of essential questions related the unit of instruction, neither did she ask questions during the class sessions. According to my observations and the journal perspectives, many of the students simply wanted information for their notes to use to study for and pass the final unit exam.

Grade Seven Post-Observation Interview—Mr. Clarke

During the post-observation interview, Mr. Clarke and I discussed (a) the student perspectives and comments written in their journals; (b) what Mr. Clarke thought went well during his instruction; and (c) what he could do to improve his instruction. When I shared the participants' journal responses with Mr. Clarke, he thought the comments were generally brief. He focused on one student's response to a journal question in which she wrote about her fascination with science and how she planned to answer her questions with her own research skills noting:

> This student is younger than the average seventh grader and she is also enrolled in a grade 10 geometry course. She is eleven years old. Her mother is actively involved in school activities. Her mother supports and motivates her daughter to be all that she can be.

Mr. Clarke's comment about this student's response supported his perspective that students in his class who do well in math also do well in science. According to Mr. Clarke, the parent's participation and involvement was also a key factor in the student's success.

Next, we discussed Mr. Clarke's "cool teacher status" and the extra hours he worked at Riverside. Mr. Clarke described himself as popular on campus, because he was also the wrestling coach. Mr. Clarke worked to establish a good working relationship with all of his students. He commented that during the wrestling season, he worked at school from 6:30 a.m. to 7:00 p.m. Mr. Clarke admitted being drained from the extra time he worked on campus. In regard to his influence with students, I mentioned the one occasion when I had a difficult time getting the participants to write in their journals. The six girls refused to work with me. When Mr. Clarke spoke to the girls and asked, "Will you do this for me?" all six girls responded immediately to his request. Overall, his students seemed to think he was a "cool teacher." From the journal perspectives and my observations inside and outside the classroom, according to the students, Mr. Clarke does everything so well, that nothing could be added to his lessons.

During the pre-observation interview, Mr. Clarke mentioned one barrier to extending his science curriculum was the lengthy process to plan field trips. During this interview, Mr. Clarke discussed that field trips could be used to improve his instruction but, the field trip policy at Riverside required him to take all 126 students enrolled in his classes on all field trips regardless of their behavioral problems. Mr. Clarke contrasted this policy with his experience with field trips in a different school district which made provisions for students who often displayed inappropriate behavior. His other complaints included the expense of the field trips, getting chaperones for every five students, and the paper work for the students, insurance, and transportation. The entire process he described at Riverside was much more “time consuming,” especially during the wrestling season.

We returned to Mr. Clarke’s previous thoughts before the observation, on science as a male-dominated field. He responded that this appears to be the way we socialize people in our society. “When we see a scientist on television, it’s always the smart male scientist.” On the contrary, Mr. Clarke admitted that he has male students who were not good with either math or science. In his opinion, the male students who struggled with both math and science were usually students who go unnoticed, because they were very quiet. In contrast, his female students who struggled with math and science appeared to receive more attention because they were more social and talkative. Mr. Clarke made an illustration using his grade distributions. As mentioned earlier, grades received by the female students tended to be higher than the grades received by the male students, largely because the female students completed more assignments.

Mr. Clarke described the class that I observed for this study as an “enigma.” All of the low achieving students from his pod were enrolled in this class. Approximately six of the students received special education services. Four of the six students were girls. There were a total of 36 students assigned to this class. Nevertheless, Mr. Clarke reported that he was "more than satisfied" with his teaching and the student participation during my observations.

> The participation from that class is always really good. I was especially satisfied with the students enrolled in special education, because they worked as hard as they possibly can. I mean all the students were on topic and they were focused. It is a joy to teach that class. I need to figure out a way to work in more activities. I would love to teach science with just activities for them. That's my goal. I am not saying that I do it badly, but I just need to really focus on and improve my direction.

The time needed to develop and complete the activities appeared to be a major factor in creating exemplary student-centered science lessons. Mr. Clarke gave an example of an activity that he and his students enjoyed at the end of the school year. The students used the classroom ceiling to illustrate the solar system. They designed the planets, moons, and stars. On average, it took approximately two weeks to complete this assignment. However, if student activities were eliminated from the unit on the solar system, Mr. Clarke could teach the unit in three days. He thought developing competence in science knowledge and understanding key concepts were more important for his students. Mr. Clarke expressed that using "well-planned" activities in his science lessons may increase the probability that the students' understanding would improve along with their retrieval, analysis, synthesis, evaluation, and application of facts and ideas.

As in the pre-observation interview, we discussed professional growth and mentoring. Mr. Clarke stated, "We have a very good female science teacher, Mrs.

Anderson who is also a mentor in our pod." He observed her teaching last year as well as her Engineering Day about two years ago. Mr. Clarke along with other teachers thought Mrs. Anderson was "outstanding." Mr. Clarke really wanted Mrs. Anderson to mentor him this school year, but stated, "I will probably start watching her more next year. I am glad to be on this team, because I have amazing, creative plans all the time, systematic, excellent instruction right here."

As an informal role model, Mr. Clarke used ideas from Mr. Brown, who seemed to value quality teaching and learning. Mr. Clarke was impressed with Mr. Brown's ability to daily assess the learning of each student daily. At this time in his career, Mr. Clarke was learning how to ask essential questions.

> I want to learn questioning techniques that elicit student interests. This will help me with group discussions and draw out knowledge from the students instead of feeding them information. I want to get all of my students involved. Teaching science really well and taking your students to the next level with quality labs is tough to do.

We talked about the large class loads and the small classroom space used for both teaching and student labs. Mr. Clarke discussed his need for more space and suggested that the lack of classroom space was another barrier to creating the more engaging science lessons that he thought were important for student learning.

> I have two classes with as many as 37 students and two classes with 24 students. I probably have one of the least appropriate rooms for science. I need enough space for class lectures and student work stations. Right now,

> we are really overloaded. I want to be busier with student activities, but I do not have the space.

We ended the post observation interview with how Mr. Clarke rated himself as a science teacher. Mr. Clarke rated himself as a good science teacher.

> I would make a great science teacher, but I am not [there], yet. I am good with kids right now. They [colleagues and administration] like me around here because the kids like me. They like me because, what I teach, the kids like to listen [to].

Mr. Clarke had very little to say about the participants' perspectives aside from being pleased that one of his female students expressed interest in a career as a scientist. Mr. Clarke knew that many students at Riverside considered him to be a "cool teacher," because he was the wrestling coach. He had a positive influence on student behavior for those enrolled in his class as well as those who were not enrolled. Even though several students received special education services, Mr. Clarke believed the class that I observed was one of his best, because the students were well-behaved and attentive during his lectures. More than 30 students were enrolled in Mr. Clarke's small science classroom, leaving almost no space for student labs. We briefly discussed why Mr. Clarke thought science was considered a male-dominated field and why female students received better grades than the male students.

Closing the post-observation interview, Mr. Clarke stated that he wanted to be a great teacher. However, to be a great teacher, he wanted a great mentor who could assist him with engaging student activities, the art of using essential questions, and daily individual student assessments. Mr. Clarke explained that their school did not have a formal teacher mentoring program. As he mentioned in the pre-observation interview, Mr. Clarke expressed a strong interest in choosing Mrs. Anderson as his informal mentor teacher. I knew Mrs. Anderson because she participated in the WISE Investments program, two years before I met Mr. Clarke. I observed Mrs. Anderson using extraordinary classroom teaching strategies with the science and technology curriculum. She received several grants and awards for using 21st century resources to integrate technology in her science curriculum. During this study, Mrs. Anderson was recruited by a high profile company to provide professional development using science and technology for K12 instructors across the United States.

Grade Seven Focus Groups

I conducted a focus group session with the parents' and a separate focus group with the female student participants in grade seven. Thirteen students and their parents were invited to participate. The same information and format used in the focus groups for grade six were used here.

Grade seven parents' focus group. Although 13 parents were invited to participate in the focus group, only two female parents participated. Even though I sent parent letters home with the students, there was no evidence that Mr. Clarke, the seventh grade science teacher encouraged the parents or their daughters to participate. The intent of the focus group was to explore parents' perspectives regarding their children's interests in science at home, in the community, and at school. Additionally, the intent was to survey their daughters' interests in careers related to science and other options. The parents rated their daughter's interests in science in all three categories as average and above average, respectively. In relationship to science interests at home their daughters showed interests in plant and animal care, and read books about astronomy, the solar system, and national geographic. In the community their daughters were involved in Girl Scouts and enjoyed visiting the science museum and the zoo. In school, their children enjoyed science experiments and projects. Both mothers did not know much about the science curriculum, but expressed satisfaction with their daughters' overall participation in science education. The parents encouraged their daughters' participation in science by attending Sally Ride workshops, assisting with science projects, and purchasing related books for research.

When asked what science related careers their daughters would be interested in, the parents mentioned careers involving veterinary medicine. One parent stated, "She wants to go to Antarctica and study penguins." The parents felt their daughters would do well working with animals. The science related careers the mothers listed for their daughters included engineering and health care worker. The two mothers reported that their daughters showed average interest in both parents' careers such as engineering and health care.

Grade seven girls' focus group. Thirteen girls were invited to take part in the focus group, but only two girls participated. I think more students would have participated if Mr. Clarke had asked them to. The girls expressed average and above average interest in science at home, in the community and at school. They enjoyed working with plants, visits to the museum and science projects. Overall the girls rated their satisfaction with science education above average. When asked what they were satisfied with in the curriculum, both expressed satisfaction with their teacher. They did not mention specific science activities, classroom assignments, or dissatisfaction with the curriculum.

Both girls reported that their parents encouraged their participation by helping with their homework. The participants discussed their interest in careers such as psychology and veterinary science. One student included that she would also do well in a traditional career such as cosmetology. When asked about their parents' careers, one student expressed an above average interest in her father's career. The other student expressed average interest in the careers of both parents. In the section that follows are my observations from the grade eight teacher interviews, science classroom observations, and student journal. In addition, I have included perspectives from two eighth-grade female students who were not enrolled in the classroom that I observed.

Grade Eight Science Instruction

Mrs. Hamilton was the eighth grade science teacher and at the time of the study had taught elementary school science for thirteen years. This was her first year as a science teacher in middle school. Her personal interest in teaching science grew from her curiosity with matter and energy. Mrs. Hamilton described her mentor teacher as "a great facilitator [who] makes it easy to ask questions."

The only community resources that were available to Mrs. Hamilton were people that she contacted. She stated that "time to make the contact for resources" was her greatest barrier. Mrs. Hamilton attended workshops to network with other science instructors who were science enthusiasts.

Like Mr. Clarke, Mrs. Hamilton's experience with girls' achievement in her science classroom was that girls had a tendency to be more successful at completing their assignments. On average, girls performed better than the boys. Overall, Mrs. Hamilton believed that girls were driven to perform better at this age. She stated, "it hasn't always been that way, because girls were not encouraged to be equals. Parent training for mom not to be 'gun shy' about math and science [is important]." Another barrier to the growth and achievement of middle school girls in science education was the instructor's lack of knowledge about the type of careers available in science.

Mrs. Hamilton thought her teacher training and preparation program was adequate. During her training she became a member of the Science Enthusiasts. With this group she had an opportunity to attend additional workshops, meetings, and trainings. However, there was no indication from our interview that Mrs. Hamilton had training on issues in science education that are related to gender equity. She strongly believed "there is a need for more workshops and a cohesive curriculum with ideas for science lessons."

I observed Mrs. Hamilton teaching a unit on genetics. While I do not discuss them in depth here, the lessons I observed over a 10-day period were to some extent consistent with the grade six and grade seven classrooms described earlier in the chapter. Mrs. Hamilton used lectures and worksheets on the Punnett Square, genetics, heredity, and chromosomal pairs. For example in one activity, the students were presented a Punnett Square that had been completed for a family with and without brown eyes (B=Brown eyes and b=not brown eyes). The students were asked to count the upper case letters in the squares and answer how many children had Brown eyes. Students used their class notes to complete worksheets and write an essay on the information they learned from the unit. During instruction, Mrs. Hamilton used a projector to demonstrate and discuss details associated with the activities. There were no opportunities for students to ask questions that were not scripted by the class materials. Overall, Mrs. Hamilton addressed few questions related to the worksheets.

The eighth grade class was a lively class of students who appeared to enjoy working cooperatively to discover the genetic codes and create drawings associated with their genetic compositions. However, before instruction, Mrs. Hamilton allowed the students to choose their partners. As a result, on at least three occasions I observed the same two female groups who had more personal conversations than on-task behaviors. In contrast, during the assignment used to illustrate families with dominant and recessive genes, several of the boys may have remained on task because they were artists and helped other students to complete their assignments.

In contrast to the grade six and grade seven observations, the students in Mrs. Hamilton's class only used paper and pencils for their science labs. I did not understand the process and the product to be a science lab activity, although my experiences as a high school teacher may have limited my understanding of science labs. I was more familiar with labs that included specialized equipment to measure, weigh, and control substances.

The *Make a Face Activity* (lab) required students to identify chromosomal pairs with dominant and recessive genes. A coding sheet included multiple rectangular shapes with upper and lower case letters, numbers, and symbols. The students used data from the dominant and recessive genes in Punnett Squares to identify characteristics in families with two children. After matching the chromosomes with facial characteristics, the students listed facial traits. The outcome of this activity involved students drawing faces of people with distinct features such as face shape, skin color, freckles, eye color, chin shape, mouth size, and eyelashes. As mentioned in Chapter 2, Duschl, et al. (2007) outlined proficiency skills in *Taking Science to School: Learning and Teaching Science in Grades K-8*. A few of the school science proficiency skills Duschl et al. described included generating and evaluating scientific evidence and explanations. The decoding activities allowed Mrs. Hamilton to teach science where the students could “test ideas and make sense out of patterns and relationships” (Collette & Chiappetta, 1994, p. 86).

During my observation, Mrs. Hamilton mentioned Gregor Mendel in her lecture and his relationship to genetics and inheritance, but she did not reference any female scientists such as Rosalind Franklin, who made contributions to understanding DNA and genetics. Another interesting observation from Mrs. Hamilton’s lessons was a comment she made during her lecture on genetics. She explained that the high rate of alcoholism in the American Indian community was attributable to genetics. I was disturbed by her comment, because she teaches students from the American Indian community. Moreover, Mrs. Hamilton did not discuss any other possible link between genetic traits and racial/ethnic groups.

There were 18 girls and seven boys enrolled in Mrs. Hamilton's eighth grade science class. All 18 girls were invited to participate in my study, but only one girl participated. The lack of interest to participate may have been the result of many factors, such as a lack of encouragement and reminders. Compared to Mrs. Jones' and Mr. Clarke's interests and responses, Mrs. Hamilton showed almost no interest in my study. In addition, Mrs. Jones and Mr. Clarke made parent contacts and helped to provide resources to support the focus groups.

Grade Eight Students' Perspectives

The one participant from Mrs. Hamilton's classroom, Cheryl reported that she felt the unit was more appealing to boys. This was surprising to me because, Cheryl was very active in the discussions and the activities. For example, Cheryl helped other students to complete their assignments. When asked what made the unit appealing to the boys, Cheryl reported, "They are all smart and like learning about that stuff." Cheryl stated the unit on genetics was also appealing to the girls because "they enjoyed drawing the faces (from codes) to figure out what they looked like." Cheryl expected to get an A or B from this unit by "[l]listening and doing all assignments," which was consistent with the "good student" identity mentioned earlier. Yet Cheryl's comments also suggested that she did not like the unit, because it may have conflicted with her religious beliefs: "I don't care what I look like. God made us just like we are." During my informal discussions with

Cheryl, she indicated that she may have been frustrated and struggling with her bi-racial identity. Cheryl could not understand why the genetic coding, used in her class, did not include multiple racial identities. Using the lens of CSS, it appeared that Cheryl may have seen her identity as a critical concept in discussing the unit on genetics, but Mrs. Hamilton did not address the students' thoughts or feelings.

Because Cheryl was the only student participant from grade eight, I was approved to shadow two female students, Alice and Lynn, in RMS's grade eight advanced math placement course. Incidentally, I met Alice and Lynn when they were enrolled in grade seven and participated in the WISE Investments program at the local university. At RMS Alice and Lynn also participated in a focus group and kept journals related to their science instruction. Even though both students expressed an above average interest in school science and interest in science-related careers, they explicitly expressed frustration with the TSS-oriented curriculum.

> I know a ton about this before it was taught. So for me, it was a snore. I'm not sure there was much they could do to make the lesson more interesting, except by putting me in a higher class. Grade-wise, I think I am safe with an "A" by a long shot. I don't even plan to get an "A," I just do. From today's lesson, I learned little that I did not already know. What a joke!

Likewise, Alice explained, "The lessons are a drag, not enough experiments, [and the] content [is] not hard enough. [We need] more content in general and more field trips." Lynn wrote, "I am not satisfied that eighth-graders are still measuring body parts, and not going into higher levels of science, like chemistry/physics."

Alice and Lynn were enrolled in the advanced math class at the local high school, but there were no advanced science classes that met their interests. Alice expressed interest in becoming a brain surgeon and Lynn wanted a career in psychology. Their parents stated that these students would do well in any career they chose. As I mentioned in the literature review, Friend and Degen (2007) proposed the need to offer district-wide Advanced Placement (AP) courses in science and English at the middle school level to improve achievement in science literacy "through exposure to more rigorous curricula" (p. 246). Girls who are successful in the middle school AP courses in science and English will be better prepared for AP science and English courses throughout high school, which in turn provides access to scholarships and college entry.

Summary

The observations from the grade six science classroom indicated that Mrs. Jones' instruction was based mostly on the TSS model. This was evident with the lectures, handouts, note taking, and rewards for predetermined questions and answers. Many of the students wanted the notes to study for the tests. Mrs. Jones presented two labs during the unit, but all students did not have an opportunity to participate with the hands-on activities because some students took over the labs without sharing the instruments. Also, the classroom space and resources used in the labs were limited. The student participants reported high interests and enjoyment with science when their science instruction included hands-on activities.

The responses from the student journals indicated the girls liked Mrs. Jones as their science teacher. When asked to express what they learned in class, most of the participants repeated information they had memorized. On several occasions, a few of the participants expressed they were bored. There were few examples that students were challenged to use higher order thinking skills such as application, analysis, and evaluation during the class session.

Overall three of the six parents and all eight student participants were satisfied with the grade six science curriculum and the grade six teachers at Riverside even though two parents reported the students needed more hands-on activities "to capture [their] interests". In addition, one parent thought the curriculum was a review and another parent stated the important need for students to [understand] future applications of science. These statements suggest that the parents wanted the science curriculum to include teaching strategies related to both the PSS and the CSS models.

The observations from Mr. Clarke's grade seven science class indicated that his primary teaching strategies were also aligned with the TSS model. During the two weeks that I observed what he described as his favorite teaching unit, there was one virtual lab and no hands-on student labs. Mr. Clarke stated he wanted to include more hands-on science activities in class, but the barriers were time and resources to create them. The classroom space was overcrowded with student desks which also posed a problem for science labs, materials, and storage.

During the interviews, Mr. Clarke expressed his need for a mentor and professional development to help improve his science activities, skills using essential questions to engage students in using critical thinking skills, and ideas to promote gender fair teaching strategies. The responses in the girls' journals indicated a high level of confidence in learning the science unit. However, the material they learned was limited to recall and taking notes for the unit exam. Overall, the students liked Mr. Clarke as their science teacher. From their perspective, Mr. Clarke's lessons were interesting and nothing was needed to improve them.

The grade eight observations included lectures and hand-on activities associated with genetics, such as using the Punnett square, decoding chromosomes, and drawing facial characteristics. Similar to the handouts in grade six, Mrs. Hamilton distributed worksheets that required students to recall basic information. Overall, the combination of lectures and handouts in the grade eight science classroom included teaching strategies associated with TSS and the PSS curricula.

To explore more about eighth grade girls and the science curriculum at Riverside, I shadowed Alice and Lynn who were eighth grade students enrolled in an advanced math course and a science class that were not part of this study. These girls were not satisfied with the curriculum used in their science classroom. Both students expressed boredom and felt that the science curriculum did not offer the rigor that they experienced in their advanced math course. Alice and Lynn expressed interest in science related careers such as a brain surgeon, bioengineer, chemical engineer, and psychologist. Their parents were supportive of their school work and career interests. Alice and Lynn’s parents agreed that the science instruction at Riverside was not designed for the advanced learner. Chapter 5 will provide a discussion of my findings and implications for gender equity and other issues in science education reform.

Chapter 5

DISCUSSION AND CONCLUSIONS

This chapter outlines the findings and implications for gender and equity in science education. I also address pre-service teacher training, professional development, and policies related to science education. My study was designed to explore the systemic practices that promote or inhibit achievement for middle school girls in their science education classroom and curriculum. A School Science Traditions Model (SST) (Zacharia & Barton, 2004) and a Contextual Systems Model (CSM) (Pianta & Walsh, 1996) were the lenses used to interpret the complex interactions associated with girls in their middle school science contexts.

For more than 40 years education have focused on the gender gap in science education and achievement. Feminist scholars argued that school science must be understood within historical, social, political, and cultural frameworks aimed at understanding policies and practices that "actively and passively block" women from participating in the sciences at the same rate as men (Barton, 1998, p. 3). Barton provided an overview of gender issues in science education from the perspective of feminist theory. In her account, early feminist scholars changed the emphasis in science achievement for girls, from a deficit perspective to analyzing girls from "structural and institutional" practices that intentionally or unintentionally maintain gender inequalities. As a result, compensatory programs were created to expose girls to experiences in science to improve their confidence, skills, and achievement.

Second wave feminists challenged the values and standards of science and science education. According to Barton (1998) scholars argued that there are multiple ways of knowing and doing science. As a practice and a culture, science is both constructed by and reflected in values held by society. The systems of science and science education are interdependent. These systems are

> connected to and influenced by . . . every other aspect of life, from religion to survival [and politics]". [As such, science is vulnerable] to human actions, interactions, and personal biases (pp. 4 - 6).

Third wave feminist scholars proposed that teachers and students co-construct scientific knowledge. As critical feminists, their analyses on girls' achievement included social categories related to race, class, and gender (Howes, 2002, p. 29). According to CSM, factors between these relationships such as the teacher/school system and the child/family system control "the kind of contemporary realities educators face" (Pianta & Walsh, 1996, p. 65) such as disproportionate achievement in science education. As a result, science literacy and science activities should be connected to communities in ways that can be useful and relevant.

The research problem began with the persistent disproportional achievement and representation of girls and women in science education and related professions. Even though the gender gap in science has decreased, results from national and international assessments consistently demonstrate that boys outperform girls in science achievement. The most recent NAEP (2009) scores indicated that across all participating states, boys scored slightly higher than girls.

Girls' unequal achievement in science may limit their access to lucrative careers and the higher incomes associated with careers in science. Over a decade ago, Eisenhart and Finkel (1998) argued that "despite indicators of academic preparation and interest that place women and men at equal levels . . . women have been and continue to be underrepresented in science and engineering workplaces, and they remain concentrated in places and work practices of lower prestige" (p. 10).

Special reports from the AAUW (2010) and NSF (2011) mirror these findings. For example, the NSF report, *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2011* concludes "[t]he science and engineering workforce is largely white and male" (p. 8). In 2006 the racial/gender demographics of scientists and engineers in science and engineering careers were: 55% white male and 18% white female; 2% African American men and 1% African American women; 12% Asian men and 5% Asian women; 3% Hispanic men and 1% Hispanic women (NSF, 2011). Most women were concentrated in careers such as nursing, teaching, and the social, biological, and life sciences. Less than 20% of the engineers employed in 2009 were women.

Some researchers have suggested girls' attitudes and self-confidence in science declines during their early years of schooling (Jones, 1997; Kahle, 1996). As age and grade levels increase, the gender gap in science scores tends to increase. Other science education researchers proposed that middle school grades are the most important years for adolescent girls who are beginning to make critical decisions related to their academic interests and future career options

(AAUW, 1996; Barton, 2008). Thus, to understand the attitudes and science achievement of girls, the focus of this study was middle school. To highlight key issues, I revisit the classroom observations, student journals, teacher interviews, and focus group interviews held with the parents and their daughters.

Classroom Observations

Classroom observations indicated that TSS, a traditional teacher-centered curriculum, was the primary instructional strategy that best characterized Riverside Middle School's science education program. In the classrooms I observed, the majority of the science lessons and activities were taught using lectures, handouts, and note-taking. In these classrooms the lessons emphasized objective knowledge and recall information. Many science education researchers have identified TSS as the least productive curriculum for improving equity, science literacy, and achievement for all students, especially girls (Baker, 1995; Baker & Piburn, 1997; Carlone, 2004; Odom, Stoddard, & LaNasa, 2007; Zacharia & Barton, 2004). TSS limits the meaning of science learning and its relationship to (or impact on) critical thinking. Despite the changes that have been made in science education, this traditional approach to teaching science has been the basic structure that has supported inequity in science education outcomes and the participation of girls. According to Odom, Stoddard, and LaNasa (2007) "[t]raditional teaching practices such as copying notes from lecture or learning scientific terms . . . provide poor learning opportunities" (p. 1330).

These issues may be compounded by other common teaching techniques. For example, student discussions related to the science lessons were most prominent in grade six with Mrs. Jones' class unit on plants, but the questions and answers tended to be controlled by the teacher. Mrs. Jones used few open-ended questions or questions that challenge and extend discussions to higher cognitive demands. To engage students in learning factual information Mrs. Jones used close-ended questions and rewarded students for correct answers. From my observation the use of tangible rewards may have placed some of the girls at a disadvantage in terms of competitiveness. Davis and Rosser (1996) argued that "many females prefer and perform better in situations where everyone wins" (p. 252).

These findings are notable because the Valley View School District has been recognized for its exemplar science program and its efforts at promoting gender equity in science. While certainly some of the classrooms in other schools may have had teachers who employed more innovative and engaging teaching practices and were attentive to issues of gender equity, these strategies were not evident in the typical classrooms in a typical middle school in this district.

Even though Riverside's science program emphasized TSS, a few of the lessons included hands-on labs. Providing students with lab activities changed the enacted curriculum from the teacher-centered focus to a student-centered focus which is more closely aligned with PSS. PSS has been a major emphasis in the current NSES (1996). PSS is an approach to equity that is designed to enhance science literacy for all students. In this study, two of the teachers made a concerted effort to include science labs in the units I observed. However, the labs had recipe-like activities with predetermined outcomes, which is a major component of the TSS curriculum. The current movement in science education is to provide inquiry labs with open-ended outcomes designed to feature the nature of science as a process with multiple ways of knowing, thinking, learning, and doing science (Carlone, 2004; Wolf & Fraser, 2008). The lessons created by the teachers' in this study may be attributable in part to constraints related to classroom space. Two of the three classrooms did not have adequate space, equipment, or resources for all students to actively participate in the hands-on activities.

Despite the lack of resources, the use of labs also does not guarantee that science activities will be more gender equitable. For example, the science lab activity taught by Mr. Clarke, in the computer lab included virtual experiments. In this setting the girls were less active than the boys. The girls' participation in the virtual science labs may have been limited by their inadequate exposure to computer literacy or computer-assisted instruction.

Findings from observations of the three science classrooms, suggested that strategies for addressing issues of equity were not evident. Gender-focused and multicultural perspectives of science were not included in any of the units I observed. For example, during the grade six unit on ecology and plant life, Mrs. Jones did not mention the work of women scientists in the grade six unit on ecology and plant life such as Ruth Patrick who is a botanists and ecologists. Likewise, in the grade seven unit on geology, Mr. Clarke did not discuss the work of female scientists.

Although students from indigenous communities were enrolled in the three classrooms, the teachers did not mention indigenous perspectives on science or the work of indigenous scholars. Even more troubling during the introduction to genetics and heredity, Mrs. Hamilton used the indigenous community to discuss alcoholism. Because Mrs. Hamilton did not include other examples of racial/ethnic groups and heredity, her lecture may be interpreted as an example of using "negative stereotyping".

Student Journals

Each of the female student participants were asked to keep journals on the science unit that I observed. Five of the seventeen participants had prior knowledge regarding the science units, even though the teachers did not actively engage these students during the lessons. The teachers may have been constrained by the time allowed for instruction. Or they may not have been trained in constructivist theory which emphasizes the importance of using the students' prior knowledge to support and facilitate the learning of new ideas. Girls who had prior knowledge of the unit expressed boredom with the science activities.

One grade six student wrote

> I knew a lot about plants in general because I had done a unit on them in 3rd grade. In third grade, along with 4th and 5th I learned a little about photosynthesis. Today's lesson was kind of boring, at least I thought. I think this lesson could have been more interesting if we had done a small lab to make us more [excited] about this new unit.

All but one of the 17 female student participants expressed high levels of self-confidence and expectations in their achievement on the science units. These girls expected to receive above average scores on their performance. To meet these personal goals, the girls planned to maintain their “good student” identities throughout the lessons by working hard to complete assignments, listening actively to lectures, and following directions. Other patterns from the students’ journal perspectives suggested that the note-taking, highlighting of key information, along with the question and answer drills helped the girls to effectively prepare for quizzes and unit exams.

While TSS teaching techniques did not deeply engage the girls in science or provide the students with in-depth content knowledge, the curriculum did support and reinforce gender norms for behavior. It appeared that the girls in this study embraced the “good student” identity in exchange for a good grade (Carlone, 2004; Duckworth & Seligman 2006). Wolf and Fraser (2008) also noted in the classrooms they observed that girls were often more concerned with completing assignments correctly than learning from experiences with uncertain outcomes used with inquiry labs in which students devise their own experiments without procedures and guidelines. The girls in Wolf and Fraser’s study were less frustrated with science lessons that offered sequential steps and predetermined outcomes used in rote memorization. Carlone (2004) and Brickhouse and Potter (2001) found similar responses from the girls in their studies who were comfortable in TSS classrooms. When science is stressed as a body of knowledge, it seems less relevant to “real-world themes and collaborative, inquiry-based problems [that have] the potential to broaden the meaning of science and scientist[s] in ways that were consistent with much of what science education reformers called for" (Carlone, 2004, p. 395). The girls' positive responses to TSS highlighted the "complexity about a gender-fair science" curriculum (p.395). That is, while girls are often more comfortable in TSS-oriented classrooms, TSS classrooms do not seem to support the types of substantive knowledge of and engagement in science that might encourage girls to pursue advanced training and careers.

To understand the participants' perspectives on their teachers' instructional practices toward equity and the science content in general, I asked the students to respond to whether the unit was most appealing to girls or boys. In relationship to the grade six unit on plants, five of the seven responses indicated that both girls and boys enjoyed the unit. One student stated

> I think this science unit was attractive to both the girls and the boys for the same and different reasons. Both the girls and the boys like the hands-on things we did. I think the girls like doing the xylem tube thing we did while the boys liked planting the seeds.

All of the student participants from the grade seven unit on geology expressed that the unit was appealing to both girls and boys. As one student noted, "the teacher tried his very best to make this unit very interesting for the whole class, not just the boys or not just the girls." Although, there is some evidence from teacher interviews that suggested the girls were performing better than boys despite the fact that the curriculum was equally appealing to all students.

Teacher Interviews

Overall, interviews with the three teacher participants suggested that they were pleased with their units and how the students responded to their instruction. All three teachers stated that the units were appealing to both the girls and boys in their classrooms. Mr. Clarke was especially pleased with his students' performance. The class that he chose for me to observe was what he called, "an enigma." Most of the students were low achievers and at least six of the 31 students enrolled in this class received special education services. Mr. Clarke expressed the following sentiment:

> The participation from that class is always really good. I was especially satisfied with the students enrolled in special education, because they worked as hard as they possibly could. I have never seen such dedicated young men and ladies. I mean all the students were on topic and they were focused. It is a joy to teach that class. I need to figure out a way to work in more activities. I would love to teach science with just activities for them. That's my goal. I am not saying that I do it badly, but I just need to really focus on and improve my direction.

All three instructors felt confident about teaching science equitably and that their pre-service training prepared them for that task although their training varied widely. While Mr. Clarke had no formal training related to female achievement in science classrooms, Mrs. Jones felt like the training she had received in college was enhanced by her summer participation in the WISE Investments Program. Mrs. Hamilton was part of a mentor group of Science

Enthusiasts. She participated in additional science education workshops, meetings, and training sessions. Despite the additional training, Mrs. Hamilton did not mention activities related to increasing gender equity associated with the Science Enthusiasts.

The three teachers had the following suggestions for teacher training programs related to gender equity for middle school science teachers. Teacher training programs at colleges and universities should include

1. more workshops, a more cohesive curriculum, or a notebook with ideas for lessons, and expertly designed activities that are aligned to the state standards;
2. provide access to background information from different careers related to science, mathematics, engineering, and technology aligned with the middle school curriculum; and
3. provide opportunities for pre-service teachers to experience the sample activities outlined in the curriculum.

All three teachers noted on average that, the girls in their classrooms received better grades than the boys because the girls completed their assignments. Mrs. Hamilton agreed with this observation and stated, “Girls are more driven at this age so they perform better. [I]t hasn’t always been that way, because girls weren’t encouraged to be equals.” Mr. Clarke also noticed that “girls who are good at math are also good in his science classes.” The teachers confirmed the self-grading reports predicted by the girls. Of the seventeen girls who formally participated in this study with the classroom observations, fifteen received a final grade above average on the science units.

The teachers were asked about community resource and barriers that inhibit their use of these resources in their classrooms. Community resources identified by the teachers included

1. parents who were experts;
2. labs using microscopes sponsored by the local university;
3. professional engineers who volunteered from local high profile corporation;
4. science museums; and
5. the public library.

These teachers' perceived the lack of time to plan for field trips and time to make the necessary contacts as barriers to drawing on these resources. The teachers identified the lack of exposure to career choices and the need for mothers to be role models in math and science as other barriers to the science achievement of middle school girls at RMS. Mr. Clarke's response suggested he had not given much thought to the barriers facing women in science.

> The only barrier I would theorize is that the subject of science is thought to be male dominated. I believe that the presence of strong science teachers, who are female, does much to dispel this belief.

To improve their instruction the teachers suggested the following resources: (a) ongoing professional development; (b) mentoring; (c) partnerships with local colleges, universities, and industries; (d) time to plan student-centered activities;

(e) financial resources; (f) material resources; and (g) space to improve access to lab activities for all students.

Parent and Student Focus Group Interviews

I held separate focus groups for the parents and the female student participants. The overall responses from both focus groups indicated that the parents and their daughters were satisfied with their experiences in the science program at RMS. Two parents stated their dissatisfaction with the curriculum. One parent remarked, “The science projects are not geared to the advanced learner. [The school did not offer] a science curriculum for students who were gifted.” Another parent commented, “ . . . students should be doing hands-on experiments at least once a week. I don’t think my daughter has done an experiment in several weeks.” The last comment mirrored the response made by one of the students in the grade eight advanced math course. RMS apparently did not have the resources to offer an advanced science course to eighth graders. Other parents’ indicated a need for class instruction that connects science activities to future careers.

Six of the girls expressed an interest in related science careers such as general medicine. Two of the girls wanted to become a veterinarian and one student expressed an interest in becoming a psychologist. Despite two of the girls’ expressed interest in science related careers, their parents thought they would do better in careers related to the social sciences and performing arts.

For the most part, parents supported their daughters’ participation in school science by involving them in activities such as: science experiments at home; visits to museums, the zoo, and national parks; science fairs; cooking; hiking and nature walks; animal care; gymnastics; snorkeling; community enrichment classes; plants; family discussions; and reading books on the solar system and subscriptions to *National Geographics*. The parents also helped their daughters with traditional homework and school projects. Two parents expressed that their husbands worked more with their daughters on science projects and homework.

I asked the parents and the students if there were topics that would place limits on learning science content. The parents and students appeared to be open to a diverse science curriculum. While there were no discussions related to critical issues in science, such as genetic engineering, there were no immediate concerns about exposing students to the critical and sometimes controversial issues that may include culture, religion, and gender.

Limitations

My case study involved the interpretation of meanings observed in patterns of behaviors in a specific middle school context located in a suburban school district in the southwest. Because of the sampling procedures, the findings from this study cannot be generalized to all areas of middle school science education. It is also impossible to determine the extent to which my presence had on the actions and responses from the participants. One of the girls in grade six wrote, “I’m glad we got to do this journal and it was great fun.” It appeared that this participant enjoyed the extra attention she received by participating in the study. Her overall participation in the science classroom activities may have improved significantly as a result of being singled out.

Summary

I conducted this study hoping to provide “a promising case” (Rodriguez, 2001) for equity and gender in the current science education reform movement. The findings from my study suggest that there is a complex relationship between the girls’ participation in school science at RMS. The current science education initiatives call for a student-centered, diverse, and progressive science curriculum that encompasses the needs of all students. While the school district had a reputation for promoting gender equity in science, the types of instruction advocated by reformers had not made deep inroads into the typical schools and classrooms across the district. In addition, the girls in my study performed better (as measured by their class grades) in the teacher-centered, traditional curriculum than the boys. Survey research on teacher practices, student attitudes, and science achievements (Odom, Stoddard, & LaNasa, 2007; Zachariah & Barton, 2004) found that girls (as well as boys) preferred a student-centered approach to learning science. As explained earlier, the student-centered approach to school science involves such activities as inquiry, hands-on labs in which students learn to construct scientific knowledge by designing their own experiments, analyzing data, and forming conclusions (Harcombe, 2001, p. 26). In contrast to the student-centered approach to learning science, other researchers who used a qualitative or mixed methods approach to examine student perceptions of their learning environment, attitudes toward science, and achievement (Wolf & Fraser, 2008; Carlone, 2004) found results consistent to those in my study.

These discrepant findings may reflect the differences between student preferences related to learning and girls' preferences for settings that allow them to receive good grades. More specifically, the girls may prefer the traditional teacher-centered, non-inquiry labs because this approach allows the girls to more easily maintain their "good student" identities. In Carlone's (2004) study the girls who participated in the student-centered inquiry labs found the activities frustrating. The girls were more concerned with completing activities correctly with the appropriate outcome. Whether or not the girls were learning science content more effectively in traditional teacher-centered learning environment is an open question. Despite the fact that middle school girls get good grades in most of their school subjects including science, their scores on standardized tests paint a different picture.

In some cases, school performance has been used to predict how well students will score on achievement tests for advanced placement courses and college entry exams. Duckworth and Seligman (2006) used mixed methods to investigate the gender differences in school grades and achievement test scores for students enrolled in grade eight. The authors proposed that "superior self-discipline helps girls less on achievement tests and minimally on tests of intellectual aptitude" (p. 205). Consistent with Duckworth and Seligman's (2006) study, the overall group mean SAT Scores (2010) indicated that boys scored better than girls in Critical Reading and Mathematics. In comparison, boys scored better than girls on the NAEP (2009) science assessment in grades four, eight, and twelve. In the advanced science scores on the NAEP (2009) boys outscored girls two to one. From a broader perspective as mentioned in Chapter 2, the southwestern state in this study is one of several states with the lowest science scores on the NAEP (2009). Good grades in school science for girls may not always predict strong learning outcomes.

Although the results of my study are less specific to gender equity, the findings provide an analysis of the general problems in science education. The findings provide additional support for what the literature has stated about the science education problem in school systems (Baker, 2007; Brotman, 2008; Rodriguez, 2001). As an interrelated system, schools should not function in isolation from the school district and the community. At the time of this study there was no clear indication that the school district and Riverside Middle School were moving toward a progressive science model that would be more engaging and teach critical thinking skills to girls and boys. Beyond the progressive model, there was little evidence of a critical science model that included the interests of the students and the needs of the local community.

We live in a global world that is marked by rapid technological change. Because technology is advancing so rapidly, science educators, school administrators, counselors, teachers, parents, students, and those who write science curriculum are challenged to keep pace with these changes in our society. As knowledge in science and technology progress in the context of science education (such as experiments in genetic engineering, nuclear energy, health, disease, the food industry, environmental conservation, etc.) students and adults will be challenged to make informed intellectual decisions in their personal and professional lives. The state science education system, teacher training programs, as well as local school systems must change to keep up with the advances in technology and scientific knowledge that are taking place nationwide and worldwide.

Future Research

Current national standards in science emphasize the need for equity and excellence in closing achievement gaps. My research was intended to build on the findings associated with gender, equity, and science education reform. While this project was designed to explore the perspectives, social interactions, and other meanings associated with science education for middle school girls, the findings are relevant to science education in general. Future research should consider using mixed methods to explore multiple sites in a middle school district or a sample of schools in a number of districts. The research should assess systemic approaches to science education reform by involving policy makers and science coordinators at the state and district levels.

According to the NSES (1996), science curricula should emphasize inquiry rather than the traditional approaches used in the earlier part of the twentieth century. Schools and communities must aim to challenge students by providing opportunities to learn science process skills and products designed for advanced investigations and laboratory activities. To sufficiently address reform initiatives in science education, students and teachers need adequate facilities, tools, materials, resources, and financial support to build communities of science learners that also allow full access for all stakeholders.

Similar to other studies (Kahle, 1998; Rodriguez 2001) the problem in science education is a systemic one. Below I offer a set of recommendations that draw from the framework proposed by Pianta and Walsh (1996) in the Contextual Systems Model. Recommendations for practice include suggestions for the school system and the child/family system including communities.

The School System

The recommendations below are presented for the school district, schools, and teachers as part of a local interrelated school system.

Districts should

1. implement system-wide professional development programs based on a needs assessment for equitable student achievement in science;
2. provide the appropriate space, material, and financial resources to include all students in lab activities; and
3. maintain and create partnerships with colleges, universities, industries, and community agencies to improve equity and excellence in the science program.

Schools should

1. feature science curricula and activities in the parent newsletter or website;
2. invite parents to visit science classrooms and participate in lab activities;

3. hold a special open house with an evening of science and science-related activities for students and their families;
4. increase rigor in the middle school science program by offering open enrollment for advanced courses such as chemistry/physics; and
5. include counseling and industry partners in promoting non-traditional career information related to science and technology.

Teachers should

1. use techniques drawn from constructivist theory when introducing a new unit;
2. acknowledge and respect the voice of all students in discussions related to their prior knowledge;
3. discuss and develop a shared definition of the nature of science to frame lessons during the school year;
4. include diverse perspectives in their science lessons;
5. use female role models with special emphasis on nontraditional careers in the science professions related to the unit lesson;
6. consider using Skype for local, national, and global access to scientists and natural phenomena;
7. implement a career day for scientists, mathematicians, engineers, and technicians;
8. plan opportunities to involve students in local scientific projects related to community needs; and

9. work collaboratively to create an integrated thematic curriculum with labs that include open-ended inquiry.

The Child/Family System

The recommendations listed below are designed to emphasize the role of the parents and the community as interrelated parts of the child/family system. Although the community is typically associated with the systems mentioned earlier, it is important to emphasize the role of the community as another important component for improving scientific literacy.

Parents should

1. understand that gender roles are changing in our global society and the importance of exposing girls to a broad variety of experiences that are often encouraged for boys;
2. advocate for advanced science education in their children's schools and the community;
3. participate with their children in science activities at home, at school, and in the community; and
4. support their child's nontraditional career interests in science, engineering, and technology.

Communities should

1. implement science mentoring programs for pre-service and classroom teachers;
2. collaborate with local businesses and industries to provide opportunities and access to resources that support improvement for science teaching and learning;

3. partner with schools and districts to implement projects and activities throughout the year with museums, zoos, science centers, parks, recreation centers, medical centers, agricultural, and other sites to offer a variety of scientific experiences; and
4. offer teacher training and professional development programs in science, engineering, technology, and related careers.

The results of my study indicated that girls in a typical school in an exemplar district are being taught using a traditional science teaching model. While the girls are receiving better grades than boys in lessons taught by this format, this is largely because the activities in these classes help them to maintain their “good student” identities. The findings also suggest that while the girls are receiving good grades they are not being exposed to rigorous science content. The school district and the school must take additional steps to transform science teaching policies and practices to improve science education and meet the needs of all students in the district.

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APPENDIX A

SCHOOL EQUITY QUESTIONNAIRE

Adapted from the Gender Equity Assessment Guide, American Association of University Women (1992), Initiative for Educational Equity
Please use the following scale to assess the six issues listed below. Write the number 1, 2, 3, 4, or 5 on the left of each statement that corresponds to your analysis and the appropriate level of assessment.

No procedures	Some consideration	Processing and writing policies	Procedures partially implemented	Procedures written in policies and fully implemented
1	2	3	4	5

1. Enrollment Patterns:

1		The district and school maintain records on enrollment and achievement patterns by gender, ethnicity, and disabilities for each subject area and course.

2. Math/Science Initiatives:

1		Girls participate in gifted science courses that reflect their proportions in the school population.
2		Professional development is available in the district for administrators, counselors, and teachers to strengthen equitable teaching and learning in science and math.
3		Guidance counselors encourage girls to continue studying science and math.

3. Curriculum:

1		The district has procedures in place to review textbooks, teaching methods, and curricula for gender bias.
2		Materials and curricula have a multicultural focus that helps students from diverse backgrounds see the contributions of all communities.

3		A multicultural curriculum is employed regardless of the makeup of the student body.
4		Gender and multicultural sensitivities are raised in every aspect of the curriculum and included in an annual review process.

4. Teachers/Counselors:

1		Educators in the school use available (on-site) curricula and background materials to assist in teaching and counseling a diverse student body.
2		The school system has policies in place and is making continuous efforts to train and implement cooperative learning for teachers in the classroom.

5. Assessment:

1		The district and school use valid and reliable assessment methods and include alternative forms of assessment for a diverse student population.
2		Counseling on secondary education career options is gender-neutral.
3		Girls receive unbiased counseling on course enrollment throughout middle school.

6. Learning Environment:

1		Teachers, counselors, administrators demonstrate equally high expectations of all students regardless of gender, ethnicity, religion, socioeconomic status, disability, etc.
2		Mentoring and job shadowing programs are available to overcome effects of bias.

3		The school creates and publicizes policies and procedures for reporting and responding to complaints of discrimination.
4		The district/school has a gender discrimination grievance policy and procedures that are accessible to all and widely advertised.
5		Students and faculty avoid collaborative silence (speak out) when students or faculty demonstrate biased behavior.

7. Additional questions, comments, suggestions:

APPENDIX B

PARENTS' FOCUS GROUP PROTOCOL

1. From your perspective, rate your daughter's level of interest in science at home, in the community, and at school.

High Interest				No Interest
5	4	3	2	1

Use the rating scale to rate your daughter's interest at home, in the community, and at school.

2. What does your daughter do that is related to science at home, in the community, and at school?

3. How satisfied are you with your daughter's overall participation in science education?

Very Satisfied				Not Satisfied
5	4	3	2	1

Use the rating scale to express your daughter's overall participation in science education.

3.1 What are you satisfied with in the curriculum?

3.2 What are you *not* satisfied with in the curriculum?

4. How do you encourage your daughter's participation in science education?

5. Are you in favor of limiting your daughter's participation in science education?

5.1 If yes, is your rationale related to: Culture, Religion, Gender, Other?

6. Has your daughter expressed an interest in science or related careers?

7. What career will your daughter *do well* in?

7.1 What is your daughter doing now to support your view that this will be a good option?

8. What science or related ***careers*** do you (both parents/guardians) participate in?

9. What science or related ***activities*** do you (both parents/guardians) participate in?

10. What level of interest has your daughter shown in your (both parents/guardians) science ***careers***? Use the rating scale.

High Interest				No Interest
5	4	3	2	1

11. What level of interest has your daughter shown in your (both parents/guardians) science ***activities***? Use the rating scale.

High Interest				No Interest
5	4	3	2	1

APPENDIX C

GIRLS' FOCUS GROUP PROTOCOL

1. From your perspective, rate your level of interest in science at home, in the community, and at school.

High Interest				No Interest
5	4	3	2	1

Use the rating scale to rate your level of interest at home, in the community, and at school.

2. What do you do that is related to science at home, in the community, and at school?

3. How satisfied are you with your overall participation in science education?

Very Satisfied				Not Satisfied
5	4	3	2	1

Use the rating scale to express your overall participation in science education.

3.1 What are you satisfied with in the curriculum?

3.2 What are you *not* satisfied with in the curriculum?

4. How do your parents encourage you to participate in science education?

5. Are your parents in favor of limiting your participation in science education?

5.1 If yes, which item is related to your parents' perspective? Culture, Religion, Gender, Other?

6. Have you expressed an interest in science or related careers?

6.1 What science career will you be interested in?

7. What career will you *do well* in?

7.1 What are you doing now to support your view that this will be a good option?

8. What science or related *careers* do both parents/guardians participate in?

9. What science or related *activities* do both parents/guardians participate in?

10. What level of interest have you shown in both parents'/guardians' science *careers*? Use the rating scale.

High Interest				No Interest
5	4	3	2	1

11. What level of interests have you shown in both parents/guardians science *activities*? Use the rating scale.

High Interest				No Interest
5	4	3	2	1

APPENDIX D

PRE-OBSERVATION TEACHER INTERVIEW PROTOCOL

Curriculum

1. Name your favorite science teaching unit/s. Why is/are it/they your favorite unit/s?
2. Do you have a science education mentor in your school? Describe your relationship/collaboration.
3. What teaching strategies and resources do you use to encourage the participation and achievement of middle school girls in science education?
4. What community resources are available for your middle school science classroom?
5. What community resources do you use in your middle school science classroom?
6. Are their barriers to your use of community resources and instruction in middle school science? If so, what are they?
7. What type of support do you receive from your district science curriculum coordinator to improve learning for girls in middle school science?

Student Achievement

8. What has been your experience with girls' achievement in your science classroom?
9. How do you compare them to middle school boys' achievement in your science classroom?
10. How would you characterize the existing status of middle school girls in science achievement in your classroom? Has this always been the case? What do you think is behind this?

11. What resources are needed to facilitate middle school girls' achievement in science?
12. What are the barriers to the growth and achievement of middle school girls in science education?

Demographics

13. How many years have you been a teacher?
14. How many years have you been a science teacher?
15. How many years have you been a science teacher in middle school?
16. How many years have you been a science teacher in this school community?

Teacher Preparation and Training

17. How adequate was your teacher training and preparation program for providing strategies for middle school girls' achievement in science?
18. What do you think should be added to the teacher training and preparation program in science education?

APPENDIX E

POST-OBSERVATION TEACHER INTERVIEW PROTOCOL

1. What was your level of satisfaction with teaching this science unit?
    - What went well?
2. What would you consider changing?
3. Were you satisfied with the overall participation for all students (i.e. female, male, students with special needs, etc.)?
4. What are the classroom demographics (i.e. ethnicity, gender, special needs)?
5. Artifacts – Examples of (completed/graded) class assignments related to the specific observations.
6. How do you define science?
7. Additional comments (resources, facilities, labs, grouping, etc.).

APPENDIX F

STUDENTS' JOURNAL PROTOCOL

Day One

1. What knowledge did you have about this unit before your teacher's instruction?
2. What could have been added to today's lesson to make it more interesting for you?
3. What overall grade do you expect to receive from this science unit?
4. How do you plan to earn this grade?
5. What did you learn from today's lesson?
6. Write any additional comments, suggestions, or thoughts about this science unit.

Day(s) Two, Three, Four, etc.

1. What did you learn from the day's lesson?
2. What could have been done to make the lesson more interesting for you?
3. Write any additional comments, suggestions, or thoughts about this science unit.

Last Day of the Lesson

1. What did you enjoy learning most from today's lesson?
2. What did you enjoy learning most from this particular science unit?
3. In your opinion, who enjoyed this science unit the most, the girls, the boys, or both girls and boys?
4. What made this science unit more attractive to the boys?
5. What made this science unit more attractive to the girls?
6. What overall grade do you expect to earn from this science unit?

7. Describe what you did (or did not do) to earn the grade for this science unit?
8. Write any additional comments, suggestions, or thoughts about this science unit.

APPENDIX G

INFORMED CONSENT

Dear Parent(s)/Guardian(s):

I am requesting you and your daughter's participation in a research project for my dissertation. My qualitative research is aimed at understanding practices in science education that promote achievement for middle school girls. The science classroom teacher has selected the girls in your daughter's science classroom to participate in this study.

You will be asked to participate in a focus group session for parents/guardians scheduled at 8:00 a.m. in the Multipurpose Room at your school. Your daughter's participation will include a focus group session, personal journal entries, and their teacher's grade distribution for the science unit. In addition, I will observe all girls as they participate in a science unit selected by their teacher. The focus group sessions will be held before school. The classroom observations should include a total of eight to ten hours. Audiotapes during the interviews will be used with the approval of the participants. The audiotapes from the sessions will be transcribed and archived for approximately five years.

The participation of you and your daughter is voluntary. If you or your daughter chooses not to participate or to withdraw from the study at any time, there will be no penalty (it will not affect your daughter's grade). The results of the research study may be published, but your name and your daughter's name will not be used.

In the 1990s our nation began to show a critical need to improve science literacy and education for all students. Your school district set a goal "to improve achievement in mathematics and science; to integrate technology into daily work and the learning lives of the students and staff; and to increase collaboration with the community." This study is designed to focus on middle school girls and their achievement in science education.

There may be no direct benefit to you or your daughter. The possible benefits of you and your daughter's participation will emphasize the need for communities, schools, and teacher training programs to design, implement, and provide resources for science instruction, curriculum, and policies that are sensitive to the needs of middle school girls and other students who may be at risk.

Sincerely,

By signing below, you are giving consent for you and your daughter in the above study.

______________________ _________________________ _____________

Signature Printed Name Date

If you have questions about you or your daughter's participation in this research or if you feel that you and/or your child have been placed at risk please contact us.

I have been informed that my parent(s)/guardian(s) have given permission for me to take part in a study concerning middle school girls and their participation, and achievement in science. I will be asked to participate in a focus group session with other girls in the study and keep a personal journal on a classroom science unit. The researcher will observe me participating in a science unit selected by my science classroom teacher. In addition, the researcher will analyze my personal journal along with my classroom grades for the science unit.

My participation in this project is voluntary and I have been told that I may stop my participation in this study at any time. If I choose to participate or not to participate, it will not affect my grade in any way.

______________________	____________________	___________
Student Signature	Printed Name	Date