An Exploratory Case Study of Upper Elementary and Middle Level Science Instruction Impacting Traditionally Underserved Students

Lucinda Howe
University of Denver

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Abstract
This is an exploratory case study looking at the practices in one Colorado K-8 school that had students performing at or above the 75th percentile on the eighth grade Science Colorado Assessment of Student Progress (CSAP) in 2009. This study attempted to answer the question: What are the instructional choices, classroom environments, interventions, and school practices in place in one K-8 school that is supporting traditionally underserved populations of students in the learning of science? This school appears to be meeting the needs of their traditionally underserved students as evidenced by the percent of students in these populations at this school that were performing at or above the proficient level on the Science CSAP in 2009, higher than both state averages and their district averages for these groups.

This study utilized two teacher survey instruments to define instructional choices and classroom environments, a revised RAND survey developed by Le et al. (2006, p. 91) and a constructivist learning environment survey developed by Johnson and McClure (2004, p. 65), CLES2(20). Questionnaires were developed to guide interviews with the principal and lead science teacher to identify resources, interventions, and professional development in place at their school. Two observation protocols were developed to systematize data pertaining to curriculum documents, the school visit, and classroom observations at each site.

In every class the primary activity was hands-on investigations, to introduce a topic of study, to further investigate a topic, and to learn about collecting and organizing data. Science notebooking was evident in every class every day. Students were not doing worksheets or reading and answering questions from the textbook. It was evident that students were safe and felt valued in each of their science classes. Student talk and collaboration was the norm in every class. Every class was highly diverse, with students of all backgrounds collaborating to investigate scientific phenomena with a plethora of science equipment, tools, and supplies. Each class had a highly qualified science teacher. The school as a whole and thereby each class had an average socio-economic level higher than the district average. School D has a principal focused on student achievement data, using them to focus planning, instruction, and interventions and there was a system of grade level collaboration that could be focused on science instruction.

One challenge noted during this exploratory case study was the weak connection at the K-5 level between the district science curriculum and the state content standards in science. The district curriculum did not articulate the science content or process skills that students are to come away with at the end of each instructional year. It would be in the district's best interest to clarify and articulate a specific sequence of science instruction. Professional development in science both at the district level and at the school level for all grades, K-8, is another challenge area for School D. Through collaborative planning would be helpful in building a more complete understanding of the science learning expectations in both content and inquiry-oriented learning goals. Professional development in inquiry processes and inquiry-based science instruction is vital to support teachers in providing the cyclical, reiterative science processes described in the literature.

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AN EXPLORATORY CASE STUDY OF UPPER ELEMENTARY AND MIDDLE LEVEL SCIENCE INSTRUCTION IMPACTING TRADITIONALLY UNDERSERVED STUDENTS

A Dissertation

Presented to

the Faculty of the Morgridge College of Education

University of Denver

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

by

Lucinda H. Howe

August 2012

Advisor: Kent Seidel, Ph. D.
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Chapter One: Introduction

Introduction

Concern over science education in the United States accelerated after World War II and again, immediately after the Soviet Union launched Sputnik I in 1957. The United States of America was rightly concerned about its capacity to compete in an increasingly technological world. The National Science Foundation tripled funding for science education, but nothing really changed in the way science was taught. Textbooks continued to drive the science curriculum, focusing on memorizing facts and preparing students for further formal studies in science (Atkin & Black, 2003). Findings cited in A Nation at Risk (National Commission on Excellence in Education, 2003) stated that “there was a steady decline in science achievement scores of U.S. 17-year-olds as measured by national assessments of science in 1969, 1973, and 1977” (p. 170) and the early international studies of U. S. students’ achievement in science prompted then President George H. W. Bush and the Nation’s governors in 1990 to propose “that by the year 2000, U. S. students should rank first in the world in science and mathematics achievement” (Medrich & Griffith, 1992, p. 1).

It is now 2012 and the trends in science have not changed, students in the USA are not out-performing their international peers from developed countries and the concerns from the 1950s resurface in The world is flat: A brief history of the twenty-first century (Friedman, 2005). More and more of our science and technology capital are
being outsourced to other countries. “The prosperity of countries now derives to a large extent from their human capital” (PISA 2006: Science, 2007, p. 3) instead of manufactured exports.

The performance of ethnic/racial and language minority students and students living in poverty continues to lag behind that of Anglo-European students (Duncan, 2006; Elmesky, 2006; Haycock, 2001; Howard, 2003; Lutkus, Lauko, & Brockway, 2006; O'Sullivan, Reese, & Mazzeo, 1997; O'Sullivan, Lauko, Grigg, Qian, & Zhang, 2003; Oakes, 1990; Smith, Banilower, McMahon, & Weiss, 2002; Vanneman, 1998). Twenty-six years ago in 1986, economist Levin, predicting dire consequences, wrote:

As the disadvantaged have increased in numbers and are projected to become a majority of the school population – and ultimately the overall population – the problem is no longer confined to that group. The potential consequences of inaction accrue to the larger society as well. These consequences include the emergence of a dual society with a large and poorly educated underclass, massive disruption in higher education, reduced economic competitiveness of the nation as well as of individual states and industries that are most heavily impacted by these populations, and higher costs of public services associated with impoverishment and crime (p. 13).

Colorado has the largest discrepancy between White individuals who have a postsecondary degree and those individuals with a postsecondary degree of the next largest ethnic/racial group - a gap of 35.8% compared to the national average of 19.3% (Gianneschi, 2008). The gap between White eighth grade students and all other groups of eighth graders in Colorado remains stagnant on the Science Colorado Student Assessment Program (CSAP) and in some cases the gap is increasing on the National Assessment of Educational Progress (NAEP; The Nation's report card, 2006; Colorado Department of Education, 2010; Grigg, Lauko, & Brockway, 2006; O'Sullivan, Jerry, Ballator, & Herr, 1997).
This study will examine the instructional practices used in one Colorado K-8 school to support ethnic/racial minority students and students living in poverty learning science. It is hoped that what may be working in this K-8 school to help address the needs of these diverse students might be beneficial for other schools with high numbers of non-White students and students in poverty.

Table 1

| Total Percentage of Eighth Grade Students in Colorado Performing at the Proficient or Advanced Level on the Colorado Student Assessment Program (CSAP) |
|---|---|---|---|---|---|---|---|---|---|
| 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
| State | 45 | 49 | 50 | 49 | 51 | 50 | 50 | 52 | 46 | 49 |
| White | 56 | 60 | 62 | 61 | 64 | 64 | 63 | 65 | 59 | 61 |
| Hispanic | 17 | 19 | 21 | 20 | 22 | 22 | 23 | 26 | 21 | 25 |
| Black | 17 | 20 | 21 | 23 | 24 | 24 | 24 | 26 | 24 | 25 |
| Asian | 44 | 50 | 51 | 54 | 56 | 55 | 56 | 60 | 55 | 60 |
| American Indian | 28 | 32 | 36 | 34 | 33 | 33 | 37 | 37 | 34 | 35 |
| Free/Reduced Lunch | | | | 23 | 25 | 24 | 25 | 27 | 23 | 26 |
| Not Free/Reduced Lunch | | | | | | | | 59 | 62 | 62 | 64 | 59 | 61 |

Note. Data for this table was retrieved from the Colorado Department of Education, Unit of Student Assessment Website, December 23, 2009

Currently and historically, the majority of Colorado students are not performing at the proficient level in science as measured by the CSAP. Table 1 shows the percentage of students scoring proficient and advanced on the Science CSAP since Colorado began testing eighth graders in 2000. Looking at the trends statewide for eighth graders, it is apparent that very little has changed in student achievement in science. Scores have been between 45% and 52% for the past ten years. During eight of those ten years the scores fluctuated right around 50% of all eighth graders scoring proficient or advanced, so half of all Colorado eighth graders are not proficient in science. While the percentage of all
ethnic minority groups has increased since 2000, the difference between White students scoring at the proficient and advanced levels and Black or Hispanic students scoring at the proficient and advanced levels has remained around 39%, fluctuating as high as 42% between White students and Hispanic students in 2004 and 2005 and as low as 35% between White students and Black students in 2008. Table 1 shows that since 2000 the percentage of Asian students performing at the proficient and advanced levels has steadily increased. On the 2009 CSAP there was only a one percent difference in performance between White students and Asian students.

The state began tracking data for students that receive free or reduced lunch in 2003. Table 1 shows students who are not receiving free or reduced lunch out-performed students receiving federal subsidy for lunches consistently by 37% until 2008 when the discrepancy decreased to 36%. In 2009 the discrepancy was 35% between students receiving free or reduced lunch and those who were not.

The state added science testing at the fifth and tenth grade levels in 2006. Table 2 shows the status of elementary science education in Colorado, with less than half of all fifth graders performing at the proficient and advanced levels. The discrepancy between White and ethnic minority students performing at the proficient and advanced levels at the fifth grade is about the same as that of eighth graders, between 34% and 37%. The exception is the performance of Asian students. Statewide Asian students at the fifth grade level are performing within five percentage points of White students at the same grade.

Similarly fifth graders receiving free or reduced lunch continued to perform well below their peers who were not receiving free or reduced lunch. Even as the percent of
Table 2
Total Percentage of Fifth Grade Students in Colorado Performing at the Proficient or Advanced Level on the CSAP

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>State</td>
<td>37</td>
<td>42</td>
<td>44</td>
<td>45</td>
</tr>
<tr>
<td>White</td>
<td>50</td>
<td>55</td>
<td>57</td>
<td>58</td>
</tr>
<tr>
<td>Hispanic</td>
<td>14</td>
<td>18</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>Black</td>
<td>16</td>
<td>20</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Asian</td>
<td>43</td>
<td>49</td>
<td>52</td>
<td>53</td>
</tr>
<tr>
<td>American Indian</td>
<td>30</td>
<td>31</td>
<td>31</td>
<td>32</td>
</tr>
<tr>
<td>Free/Reduced Lunch</td>
<td>16</td>
<td>20</td>
<td>21</td>
<td>23</td>
</tr>
<tr>
<td>Not Free/Reduced Lunch</td>
<td>50</td>
<td>55</td>
<td>57</td>
<td>60</td>
</tr>
</tbody>
</table>

Note. Data for this table was retrieved from the Colorado Department of Education, Unit of Student Assessment Website, December 23, 2009

proficient and advanced students increased, the discrepancy between students receiving free and reduced lunch and those who were not increased as well.

**Statement of the Problem**

In Colorado the science educational needs of half of all students, particularly ethnic/racial minority students and students of poverty, have not been met. The CSAP data in science from the Colorado Department of Education (CDE) clearly shows that Colorado ethnic/racial minority students and students living in poverty continue to perform well below the state average (Table 1 and Table 2). One possible reason for this lower performance on the CSAP of ethnic minority students and students living in poverty could be that the recommendations proposed by the *National science education standards* (NSES) and *Inquiry and the national science education standards* are not being used in all Colorado schools for all students. Due to the emphasis and consequences of No Child Left Behind (NCLB) on literacy and math, it is possible that the first time students are exposed, with any depth, to science is when they get to the
middle grades. It is also possible that science inquiry and hands-on, minds-on activities are not an integral part of a school’s science program.

**Research Question**

There are, however, schools in Colorado that have been meeting the science needs of the majority of their students. Table 3 shows disaggregated data for four such schools in 2009. The majority of students attending School D were proficient and no differences were noted among ethnic/racial minority students in the percent of proficiency. In 2009 students receiving free/reduced lunches out-performed students who were not.

It would be interesting and important to science educators and administrators to investigate what this school is doing for all their students, but particularly for their ethnic/racial minority students and students living in poverty. Could the educational practices at this school be beneficial for other schools in Colorado with similar populations of students?

This study explored the question:

<table>
<thead>
<tr>
<th>2009</th>
<th>State</th>
<th>District 1</th>
<th>School A</th>
<th>District 2</th>
<th>School B</th>
<th>District 3</th>
<th>School C</th>
<th>District 4</th>
<th>School D</th>
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<tbody>
<tr>
<td>Total</td>
<td>49</td>
<td>60</td>
<td>81</td>
<td>49</td>
<td>69</td>
<td>53</td>
<td>70</td>
<td>53</td>
<td>71</td>
</tr>
<tr>
<td>White</td>
<td>61</td>
<td>67</td>
<td>89</td>
<td>58</td>
<td>72</td>
<td>77</td>
<td>86</td>
<td>59</td>
<td>71</td>
</tr>
<tr>
<td>Hispanic</td>
<td>25</td>
<td>31</td>
<td>56</td>
<td>29</td>
<td>48</td>
<td>34</td>
<td>54</td>
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<td>a</td>
<td>a</td>
<td>a</td>
<td>23</td>
<td>76</td>
</tr>
<tr>
<td>Free Lunch</td>
<td>26^b</td>
<td>28</td>
<td>a</td>
<td>27</td>
<td>43</td>
<td>26</td>
<td>a</td>
<td>21</td>
<td>71</td>
</tr>
<tr>
<td>Not Free/Reduced</td>
<td>61</td>
<td>69</td>
<td>83</td>
<td>63</td>
<td>74</td>
<td>65</td>
<td>76</td>
<td>51</td>
<td>67</td>
</tr>
</tbody>
</table>

Note. Data for this table was retrieved from the Colorado Department of Education, Unit of Student Assessment Website, January 30, 2011().

^aLess than 16 students in population group. ^bState reported Free/Reduced Lunch together.
What are the instructional choices, classroom environments, interventions, and school practices in place in one K-8 school that is supporting traditionally underserved populations of students in the learning of science?

**Statement of Significance**

If we can peek into a school in which racial/ethnic minority students and students living in poverty are successful in science here in Colorado, the educational community might be able to create places where all students will be able to participate in the mainstream instead of being left on the outskirts of educational opportunity and future employment opportunity. Science not only teaches young people interesting facts about the world around them, but more importantly teaches students how to think, how to solve problems, how to plan and organize, how to observe and provide evidence to support their ideas, and how to communicate their understandings, all important skills for the 21st century (Bransford & Donovan, 2005; National Research Council, 1996; Yager, 2004).
Science Achievement

International trends.

The United States of America participated in three international studies on science achievement comparing the USA to other developed countries before 1990: the First International Science Study nearly 40 years ago, between 1966 and 1973, testing 10-year-old students from 16 countries, 14-year-old students from 18 countries, and students in their last year of secondary school from 18 countries, the Second International Science Study, between 1983 and 1986, testing the same age-groups, and finally the United States participated in the First International Assessment of Educational Progress, in 1988, involving 13-year olds from six countries. Even though the data is “technically problematic” (Medrich & Griffith, 1992, p. 23), exhibiting sampling issues, “students from the United States, regardless of grade level, generally lag behind many of their counterparts from other developed countries in both mathematics and science achievement” (Medrich & Griffith, 1992, p. 29).

Data analysis of these early international studies led the International Association for the Evaluation of Educational Achievement (IEA) to develop the Third International Mathematics and Science Study (TIMSS) in 1995, the Third International Mathematics and Science Study – Repeat (TIMSS-R) in 1999, and the TIMSS in 2003. Eighth grade students in the USA performed consistently higher than the international average on all
three assessments even though they were out performed every year by Singapore, Japan, Republic of Korea, and Hungary (Beaton et al., 1996; Gonzales et al., 2001; Gonzales et al., 2004). United States eighth graders did show significant improvement in their scale scores in 2003 compared to 1995 and 1999, improving by 15 and 12 scale points respectively (Gonzales et al., 2004, p. 17). In 1995 thirteen percent of eighth grade students in the USA scored in the top ten percent internationally (Beaton et al., 1996, p. 31). In 1999 the percent of eighth graders scoring in the top ten percent increased to fifteen percent (Gonzales et al., 2001, p. 15).

In 1997 the Organisation for Economic Co-operation and Development (OECD) launched the OECD Programme for International Student Assessment (PISA) in response to a “need for cross-nationally comparable evidence on student performance” (PISA 2006: Science, 2007, p. 3). The TIMSS assessed science content knowledge while the PISA assessed science process skills within a science content context. The major difference between the TIMSS and the PISA is the focus of the PISA on 15-year olds’ “ability to apply scientific concepts and thinking skills to everyday non-school situations” (Nohara, 2001). While eighth graders performed above the international average on the TIMSS, fifteen year olds from the United States performed well below the international average with twenty-two countries performing statistically better on the PISA 2006, Finland, Canada, Japan, and Czech Republic, 22 countries performing significantly lower, Mexico, Turkey, Greece, and Portugal, and twelve countries having no significant difference in their scores, Croatia, Iceland, Latvia, Slovak Republic, and Luxembourg (PISA 2006: Science, 2007).
The PISA 2006 compared proficiency levels of students within each nation as well with Level 6 being the highest proficiency and Level 1 being the lowest proficiency level. The international average percent of students performing at or above Level 5 was nine percent and nine percent of the students in the U.S. achieved at or above Level 5, right at the international average. Finland, the top scoring country on the PISA 2006, however had 20.9% of its 15 year olds scoring at or above the Level 5 proficiency. The percent of students performing at the lowest levels, below Level 2, in the U.S. is 24.4%, significantly higher than the highest performing nations. Approximately 50% of 15 year olds in the United States scored at the Level 2 or Level 3 proficiency on the PISA 2006 \((PISA\ 2006:\ Science,\ 2007)\).

**National trends.**

The National Assessment of Educational Progress (NAEP) found “that despite some small recent gains, the average performance of 17-year olds in 1986 remained substantially lower than it had been in 1969” (Rutherford & Ahlgren, 1990, p. xv). The trend continued through the 1996 assessment (Vanneman, 1998). Trend analysis for 13-year olds on the science NAEP from 1970 to the 1996 assessment showed that the average scores had not changed in 26 years (Vanneman, 1998). In fact, as recent as the 2005 NEAP, the overall scores in science for eighth grade students in the U. S compared to the results in 1996 and 2000 were unchanged at 149 score points. The performance levels of eighth graders also showed “no significant changes in the percentages of students performing at or above the Proficient level and at or about the Basic level compared with either previous assessment year” (Grigg et al., 2006, p. 18). Since the
1996 NAEP has analyzed the performance difference between racial/ethnic student groups and lower-income students, also called the achievement gap. Not surprisingly, White students continued to perform higher than all other racial/ethnic groups. “Black students were the only racial/ethnic group to make significant gains, increasing from 121 score points in 1996 to 124 in 2005” (Grigg et al., 2006, p. 20). Scores for Hispanic students remained unchanged since 1996. The gaps between student groups have remained unchanged. The 37-point gap between White and Black students in 2005 was not significantly different from previous years neither was the 32-point gap between White students and Hispanic students (Grigg et al., 2006). O’Sullivan, Reese, and Mazzeo (1997) included in their analysis the performance scores of American Indian students in 1996 and 2000. They noted on the 1996 assessment that “American Indian students had higher average scores than Black students and Hispanic students in grade eight” (1997, p. 30). In 2000 the scale scores for American Indian students decreased from 148 to 134 (O’Sullivan et al., 2003). The gap between students who are eligible to receive free or reduced-price lunch and those students who are not continues; even though the scores of students eligible increased significantly from 2000, the scores were not significantly different from scores in 1996 (Grigg et al., 2006). Of all students performing at or above the Proficient level on the 2005 assessment 83% were White students, 16% were eligible for free-reduced-price school lunch, and only 7% reported speaking a language other than English at home (Grigg et al., 2006).
Colorado trends.

Colorado participated in the NAEP Science assessment at the eighth grade in 1996 and 2005. Overall students in Colorado scored higher than their peers in 22 of 45 other jurisdictions that participated in 2005, higher than the national average. However, eighth grade students’ scale scores in 2005 were unchanged from the 1996 assessment at 155. Between 1996 and 2005 the scale scores of White eighth grade students and students not eligible for free/reduced-price school lunch increased significantly while the scores of Black and Hispanic eighth graders and students eligible for free/reduced-price school lunch did not change significantly thereby increasing the performance gap between these groups of students (The Nation’s report card, 2006).

Colorado uses the Colorado Student Assessment Program (CSAP) to assess students’ progress in science. The percent of eighth graders performing at the proficient or above level has held steady between 45% and 52% for the past ten years. While the percentage of all ethnic minority groups has increased since 2000, the difference in performance between White students scoring at the proficient and advanced levels and Black or Hispanic students scoring at the proficient and advanced levels has remained around 39%. Students who are not receiving free or reduced lunches out performed students receiving federal subsidy for lunches consistently by 37% until 2008 when the discrepancy decreased to 36%. In 2009 the discrepancy was 35% between students receiving free or reduced lunches and those who were not.
Standards-based Science Education

Considering the historical trends of science proficiency on a global level, a national level, and at the state level, it is clear to see that all students in the United States could improve their proficiencies in science. In 35 years, between 1970 and 2005, science scores have not improved. Even more disturbing, the performance gap between White students and ethnic minority students and students of poverty not only has not decreased, it has increased. This is happening at a time when the need for a scientifically and technically literate population is increasing worldwide thereby widening the gap between those who can participate in science related fields and those who can’t.

A standard can be defined as “an authoritative principle or rule that usually implies a model or pattern for guidance, by comparison with which the quantity, excellence, correctness, etc., of other things may be determined” (Standard). Bybee (1997) identifies standards as “several things, including commitments to certain goals for science education, measurements of attainment, context for professional discourse, and criteria to assess curriculum, teaching, and assessments” (p. 191). The National science education standards (NSES) states that

science education standards are criteria to judge quality: the quality of what students know and are able to do, the quality of the science programs that provide the opportunity for students to learn science; the quality of science teaching; the quality of the system that supports science teachers and programs; and the quality of assessment practices and policies (National Research Council, 1996, p. 12).

The NSES was published in 1996 after A Nation at risk in 1983 that challenged the then current educational system as a whole, Science for all Americans in 1989 which set out to “identify a minimal core of critical understandings and skills, whether or not they happen
to be part of current school curricula” (Rutherford & Ahlgren, 1990, p. xx), and

*Benchmarks for science literacy*, first published in 1993, that built from the foundation set by *Science for all Americans*, and set out to map “how students should progress toward scientific literacy, recommending what all students should know and be able to do by the time they reach certain grade levels” (American Association for the Advancement of Science, 2009, Introduction, para. 1).

The central premise of the NSES is that science is an active process not something that is done to students, but an endeavor that students participate fully in, asking questions, constructing explanations, testing those explanations, and communicating their new understandings to others. With this premise in mind committees worked and defined standards for science teaching, professional development for teachers of science, assessment in science education, science content, science programs, and science education systems (National Research Council, 1996). Within the science content standards there are eight categories. In addition to the three traditional science strands of physical, life, and earth science there are categories describing standards for unifying concepts and processes in science, science as inquiry, science and technology, science in personal and social perspectives, and history and nature of science (National Research Council, 1996, p. 104).

Colorado first adopted the *Colorado model content standards: Science* in June of 1995. Colorado science educators used the *Benchmarks for science literacy* and worked from the National Research Council’s (NRC) National Science Education Standards Project to develop the state’s first science standards. This document described six
standards; three content areas of physical, life, and earth science, one addressing inquiry, two covering the nature and technology of science. They included benchmarks at grade groupings similar to the Benchmarks. These standards were then revised in February of 2007 “to: 1) reduce redundancies in standards and benchmark statements, 2) replace curricular activities and test questions ….with statements of the concepts that they represented and 3) identify and fill any gaps” (Colorado Department of Education, 2007, p. 3) with very little substantive changes. Standard five and six were collapsed into one standard. The bank of science questions for the CSAP was developed using these standards and benchmarks.

In December of 2009 the Colorado Department of Education adopted Colorado academic standards: Science with significant changes from the earlier standards document. The development of the new standards started with what prepared high school graduates should be expected to know; they came up with ten big ideas in science that all graduates of Colorado high schools should have mastered. The committee seemed to have listened to the criticism of the NSES by the National Research Council in Taking science to school: Learning and teaching science in grades K-8 when they wrote that there were too many topics and little guidance about which topics were most critical and how the topics were not sequenced appropriately when considering the development of children’s understandings (2007). They then used The atlas for science literacy to sequence appropriate learning at each grade level, Pre-K through eighth grade instead of grade groupings as in previous standards. Another change is the move from five standards to three standards; embedding scientific inquiry and process skills and 21st
century skills into the three science content areas of physical, life, and earth sciences (Colorado Department of Education, 2009).

Since Colorado has no state curriculum, local school districts create their own curriculum, designing their own sequence of instruction in order to meet the state standards that are assessed on the CSAP in science. This leaves a possibility for a wide range of different science curriculums and sequences of curriculum among the 178 districts in Colorado. Research shows that schools that are laser focused on common goals outperform schools that are not (Barth et al., 1999; Fullan, Hill, & Crévola, 2006; Reeves, 2002; Schmoker, 1996; Schmoker, 2001; Schmoker, 2006).

**Scientific Literacy**

The goal of the NSES, *Science for all Americans*, and the *Benchmarks* is to attempt to iterate what students need to know, understand, and be able to do in order to become scientifically literate. NSES defines scientific literacy as “the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity” (National Research Council, 1996, p. 22). Some are of the opinion that it is necessary for every citizen to be scientifically literate in order to participate fully in our democratic society and global economy (Aikenhead, 2006; C. W. Anderson, 2007; Bybee, 1997; Gonzales et al., 2001; National Research Council, 1996; National Research Council, 2007; Nelson, 1999; Roth & Barton, 2004; Rutherford & Ahlgren, 1990; Vasquez, 2008). Roth and Barton (2004) go on to say that “critical scientific literacy is inextricably linked with social and political literacy in the service of social responsibility” (p. 10). As the global economy becomes
even more interconnected and technological, a well informed and thoughtful constituency will be necessary to make knowledgeable and considered decisions. Vasquez (2008) says that scientific literacy is “more critical than ever given growing reliability on science and technology and all the problems and possibilities they provide for our future” (p. 4).

“America’s competitive edge in the ‘flat world’, its strength and versatility, all depends on an education pipeline capable of producing a steady supply of young people well prepared in science and mathematics” (Vasquez, 2008, p. 101).

The need for and importance of scientific literacy is extensively described in the literature, but what does it mean to be scientifically literate? It is difficult to find consensus. The NSES includes a comprehensive list of proficiencies in a scientifically literate individual. One who is scientifically literate can:

1. Ask, find or determine answers to questions (National Research Council, 1996, p. 22; Roth & Barton, 2004)
3. Read and understand articles about science in popular press (National Research Council, 1996, p. 22)
4. Identify scientific issues underlying national and local decisions (Gonzales et al., 2001; National Research Council, 1996, p. 22)
5. Evaluate the quality of scientific information (National Research Council, 1996, p. 22; National Research Council, 2007), and
6. Pose and evaluate arguments based on evidence and to apply conclusions appropriately (National Research Council, 1996, p. 22; Vasquez, 2008)

Science for all Americans offers a more global description of scientific literacy:

The American Association for the Advancement of Science (AAAS) believes that the science literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes (1990, p. xvii).

Scientific proficiency is defined more succinctly in Taking science to school (National Research Council, 2007) as the ability to know, use, and interpret scientific explanations of the natural world, generate and evaluate scientific evidence and explanations, understand the nature and development of scientific knowledge, and participate productively in scientific practices and discourse. Sutman (1996) offers an even more succinct definition, stating that “an individual is science literate when that person is able and willing to continue to learn science content, to develop science processes on his or her own, and able to communicate the results of this leaning to others” (p. 459). The OECD states that “scientific literacy requires an understanding of scientific concepts, as well as the ability to apply a scientific perspective and to think scientifically about evidence” (PISA 2006: Science, 2007, p. 21). This is the definition that OECD used to construct the PISA.

Shamos (1995) argues that achieving scientific literacy at all is a myth. He does, however, describe the highest level of scientific literacy he calls “true” scientific literacy. At this level the individual actually knows something about the overall scientific enterprise. He or she is aware of some of the major conceptual schemes (the theories) that form the foundations of science, how they were arrived at, and why
they are widely accepted, how science achieves order out of a random universe, and the role of experiment in science. This individual also appreciates the elements of scientific investigation, the importance of proper questioning, of analytical and deductive reasoning, of logical thought processes, and of reliance upon objective evidence (p. 89).

Shamos goes on to say that “conventional science education has clearly failed to achieve its goal of a scientifically literate public. In the entire history of the American science education movement, we have never managed to attain so lofty a goal, and some believe, we never will” (1995, p. 140). These definitions leave the door open to many different interpretations of the foundational goal of science education. These floundering, incoherent science curricula with multiple, splintered and ill-defined goals can very likely leave out students of ethnic/racial minorities, language minorities, and students of poverty.

Instructional Choices in Science

If the goal is a scientifically literate population, what are the best instructional choices that a teacher, school, or district can make? Traditionally methods of instruction “emphasize the learning of answers more than the exploration of questions, memory at the expense of critical thought, bits and pieces of information instead of understandings in context, recitation over argument, reading in lieu of doing (Nelson, 1999; Rutherford & Ahlgren, 1990). The dichotomy expressed above is not new. Dewey (1938) in comparing “traditional” education with “new” education expressed these views; “to learning from texts and teachers, learning through experience; to acquisition of isolated skills and techniques by drill, is opposed acquisition of them as means of attaining ends which make direct vital appeal” (p. 5).
After Sputnik was launched, during the 1950s and 1960s, scientists created investigation-focused and more updated science curricula, but when they got presented to students it was in the form of lecture or students taking turns reading the text. Students had little “opportunity to develop the depth of understanding [from a] deep and direct contact with the phenomena” (Atkin & Black, 2003, p. 37). These programs however were driven by the experts, university-based scientists, and teachers were only consulted when it was time to write the teachers’ guides. There was an attempt to make the curricula teacher proof. “Considerable emphasis was placed on writing new textbooks, sometimes with the explicit intention of limiting the latitude of teachers to make changes” (Atkin & Black, 2007, p. 803).

As stated in the NSES there is a changing emphasis from a content focus, memorizing details and facts, to science process skills in a science context, “doing more investigations in order to develop understanding, ability, values of inquiry, and knowledge of science content” (National Research Council, 1996, p. 113). Dewey (1938) in his work *Experience and education* articulated his position as the “scientific method is the only authentic means at our command for getting at the significance of our everyday experiences of the world in which we live” (p. 111). Other authors agree with Dewey that students’ experiences are the foundation of their educational experience in science (Bransford, Brown, & Cocking, 2000; Bybee, 2006; National Research Council, 1996; Vasquez, 2008). The term that has been used for over half a century to describe the ideal science learning environment is inquiry or inquiry-based instruction.
Inquiry-based instruction.

Inquiry has been defined as a seeking or request for truth, information, or knowledge; the act of inquiring or of seeking information by questioning (Inquiry). Anderson (2007) points out that “inquiry has been a prominent theme of science curriculum improvement efforts ever since the post-sputnik era NSF-funded science education endeavors appeared in the headlines of the late 1950s” (p. 807). The NSES defines scientific inquiry as the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (National Research Council, 1996, p. 23).

Vasquez (2008) refers to three legs of the inquiry stool; “the ability to do scientific inquiry, understanding why scientific knowledge changes, and inquiry as a set of teaching methods” (p. 12). Anderson (2007) analyzed the NSES and found that there were three categories of the use of inquiry; scientific inquiry, referring to the ways that scientists do their work, inquiry learning, students asking and answering their own questions, and inquiry teaching, teachers investigating the best ways to teach their content and analyzing factors that contribute to their students’ learning science.

The mistake would be to confuse inquiry-based instruction with hands-on classroom activities or laboratory experiences. “It is not enough to insist upon the necessity of experience, nor even upon the necessity of activity in experience. Everything depends upon the quality of the experience which is had” (Dewey, 1938a, p. 16). Scientific investigations can range from highly structured, cookbook oriented, where the
question and the outcome are known beforehand to open, free-ranging explorations, where the problem, as well as the method and the conclusion are left open (Herron, 1971; National Research Council, 1996; National Research Council, 2007; Roth, 2006a). The outcomes at different places on this continuum are not, however, the same. Bransford and Donovan (2005) believe that “lockstep approaches shortchange observation, imagination and reasoning” (p. 405). Roth (2006a), in response to concerns about performance on tests of scientific knowledge, responded with:

Doing open-inquiry laboratory activities, however, student develop scientific inquiry and technical skills, they learn how these are connected to specific scientific concepts, and they become adept at dealing with situations that are not clearly defined. That is, beside science, they learn about the nature of science (p. 58–59).

The National Research Council (2007) agrees; “rather than teaching individual skills separately and having students practice them, skills can be taught as needed, in the context of a larger investigation linked to questions developed with students” (p. 255).

When one looks back at the definition of inquiry the focus is on questioning. This is true of scientific inquiry as well (Karplus, 2002; Magnusson & Palincsar, 2005; National Research Council, 1996; National Research Council, 2000; National Research Council, 2007; Rutherford & Ahlgren, 1990; Yager, 2004). “Inquiry is intimately connected to scientific questions – students must inquire using what they already know and the inquiry process must add to their knowledge” (National Research Council, 2000, p. 13). When students ask their own questions they are more apt to be fully engaged (Roth & Barton, 2004; Roth, 2006a). “[S]tudents who frame, conduct, and report their own research are much more interested and motivated, and as a result, come to
understand science in a much deeper way” (Roth, 2006, p. 58). Magnusson and Palinscar (2005) add that “repeated cycles of investigation allows students to ask the same questions in new contexts and new questions in increasingly understood contexts as they work to bring their understanding of the world in line with what scientists think” (p. 426). This idea parallels Herron’s (1971) who talks explicitly and repeatedly about the “dynamic – revisionary component . . . as one of the unique characteristics of scientific enquiry” (p. 181).

As students design their methods of investigating the answers to their own questions they must consider the effects of different variables, those that they must control and those that they can change. This allows students to develop higher-order process skills (National Research Council, 2007; Roth, 2006a; Rutherford & Ahlgren, 1990). Taking science to school (2007) states:

Instruction about control of variables improved children’s abilities to design informative experiments, which in turn facilitated conceptual change in a number of domains. They were able to design unconfounded experiments which facilitated valid causal and noncausal inferences, resulting in a change in knowledge about how various multivariable causal systems worked (National Research Council, 2007, p. 151).

“Science demands evidence” (Rutherford & Ahlgren, 1990, p. 5). It doesn’t matter which discipline of science one is involved in, evidence is needed to support scientific ideas and explanations (Magnusson & Palinscar, 2005; National Research Council, 1996; National Research Council, 2007; Rutherford & Ahlgren, 1990). Dewey stated in 1938 over forty years before Science for all Americans that:

. . . the method of intelligence manifested in the experimental method demands keeping track of ideas, activities, and observed consequences. Keeping track is a
matter of reflective review and summarizing, in which there is both discrimination and record of the significant features of a developing experience (p. 110).

“As students conduct investigations to develop and apply explanations to natural phenomena, they engage in scientifically oriented questions, give priority to evidence in responding to questions, formulate explanations from evidence, make connections to scientific knowledge, and communicate and justify explanations.”

Table 4

Essential Features of Classroom Inquiry and Their Variations

<table>
<thead>
<tr>
<th>Essential Feature</th>
<th>Variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Learner engages in scientifically oriented questions</td>
<td>Learner poses a question</td>
</tr>
<tr>
<td></td>
<td>Learner selects among questions, poses new questions</td>
</tr>
<tr>
<td></td>
<td>Learner sharpens or clarifies question provided by teacher, materials or other source</td>
</tr>
<tr>
<td></td>
<td>Learner engages in question provided by teacher, materials, or other source</td>
</tr>
<tr>
<td>2. Learner gives priority to evidence in responding to questions</td>
<td>Learner determines what constitutes evidence and collects it</td>
</tr>
<tr>
<td></td>
<td>Learner directed to collect certain data</td>
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<tr>
<td></td>
<td>Learner given data and asked to analyze</td>
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<tr>
<td></td>
<td>Learner given data and told how to analyze</td>
</tr>
<tr>
<td>3. Learner formulates explanations from evidence</td>
<td>Learner formulates explanations after summarizing evidence</td>
</tr>
<tr>
<td></td>
<td>Learner guided in process of formulating explanations from evidence</td>
</tr>
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<td></td>
<td>Learner given possible ways to use evidence to formulate explanation</td>
</tr>
<tr>
<td></td>
<td>Learner provided with evidence</td>
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<tr>
<td>4. Learner connects explanations to scientific knowledge</td>
<td>Learner independently examines other resources and forms the links to explanations</td>
</tr>
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<td></td>
<td>Learner directed toward areas and sources of scientific knowledge</td>
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<td></td>
<td>Learner given possible connections</td>
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<tr>
<td>5. Learner communicates and justifies explanations</td>
<td>Learner forms reasonable and logical argument to communicate explanations</td>
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<td></td>
<td>Learner coached in development of communication</td>
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<td></td>
<td>Learner provided broad guidelines to use and sharpen communication</td>
</tr>
<tr>
<td></td>
<td>Learner given steps and procedures for communication</td>
</tr>
<tr>
<td>More or less amount of learner self-direction</td>
<td>More or less amount of direction from teacher or materials</td>
</tr>
</tbody>
</table>

Note. Adapted from *Inquiry and the National Science Education Standards* by National Research Council, p. 29. Copyright 2000 by the National Academy Press.
phenomena, they develop claims, defend them with evidence, and explain them, using scientific principles” (National Research Council, 2007, p. 258). As students’ claims are formulated they are looking for patterns and relationships in their data, connecting new information to their prior knowledge, analyzing alternative explanations, and communicating their explanations and the supporting evidence to the larger community (Bransford & Donovan, 2005; Donovan & Bransford, 2005; Magnusson & Palincsar, 2005; National Research Council, 1996; National Research Council, 2007; Rutherford & Ahlgren, 1990). Inquiry and the national science education standards summarizes the essential features of classroom inquiry in Table 4, showing the continuum from more student-centered to more teacher-centered.

**Constructivist instruction.**

Constructivist learning is akin to inquiry learning, but has an “even greater potential for misunderstanding” (R. D. Anderson, 2007, p. 809). Osborne (1996) explains:

The nature of science has no necessary bearing on the nature of teaching and learning science, for the former is a philosophical issue to do with the nature of science while the later is an educational issue to do with the best way of educating nonscientists about science (p. 67).

This is why Anderson speculates that the NSES uses the word inquiry instead of constructivism. Anderson (2007) lists four elements of constructivist – as well as inquiry learning:

1. Learning is an active process of individuals constructing meaning for themselves; significant understandings are not just received.
2. The meanings each individual constructs are dependent upon the prior conceptions this individual already has. In the process, these prior conceptions may be modified.
3. The understandings each individual develops are dependent upon the contexts in which these meanings are engaged. The more abundant and varied these contexts are, the richer are the understandings acquired.

4. Meanings are socially constructed; understanding is enriched by engagement of ideas in concert with other people (p. 809)

Von Glasersfeld (1988) refers to Vico’s 1710 treatise *De Antiquissima Italorun Sapientia* to explain a basic constructivist idea that individuals “can know nothing but the cognitive structures they themselves have put together” in other words, “the human knower can know only what the human knower has constructed” (von Glasersfeld, 1988, p. 3). With this premise it is clear that the emphasis should be on the learner; it is the learner who is constructing meaning in any activity (R. D. Anderson, 2007; Dewey, 1938a; von Glasersfeld, 1993; Vygotsky, 1962; Yager, 1991). Social constructivists include the caveat that learning must also happen through a variety of contexts and within a social structure not just strictly within the “knower’s” own mind (R. D. Anderson, 2007; Bransford & Donovan, 2005; Bybee, 1997; Tobin & Tippins, 1993; Vygotsky, 1978; Yager, 1991). Bybee (1997) describes the concept well:

The constructivist view assumes a dynamic and interactionist conception of human learning. Students bring to a learning experience their current explanations, attitudes, and skills. Through meaningful interactions between themselves and their environment, which includes other students and teachers, they redefine, replace, and reorganize their initial explanations, attitudes, and skills (p. 167).

It takes carefully structured experiences to focus the experience on the desired learning outcome and to activate students’ prior knowledge (Bransford & Donovan, 2005; Bybee, 1997; Donovan & Bransford, 2005; National Research Council, 2000; National Research Council, 2007; Vasquez, 2008; Yager, 1991). Vygotsky (1962) referring to a child’s prior understanding and explaining that thoughts and concepts are
connected in systems wrote “concepts do not lie in the child’s mind like peas in a bag, without any bonds between them” (p. 110). Von Glasersfeld used the word scheme to explain how new information is integrated into previous concepts. “Cognitive change and learning takes place when a scheme, instead of producing the expected result, leads to perturbation, and perturbation, in turn, leads to accommodation that establishes a new equilibrium” (von Glasersfeld, 1988, p. 7). Donovan and Bransford write that it is important to “provide opportunities for students to experience discrepant events that allow them to come to terms with the shortcomings in their everyday models” (2005, p. 569-571). In a practical sense, for example, it is pointless to teach science vocabulary words in isolation of experience or prior knowledge (Bransford & Donovan, 2005; National Research Council, 2000; von Glasersfeld, 1993; Vygotsky, 1962; Yager, 1991; Yager & Lutz, 1994). “Practical experience also shows that direct teaching of concepts is impossible and fruitless. A teacher who tries to do this usually accomplishes nothing but empty verbalism, a parrot like repetition of words” (Vygotsky, 1962, p. 83).

Osborne argues that constructivist instruction in the purest sense falls short of the goal of a firmly grounded science education. He writes:

concepts of fair testing, the identification and control of variables, the generation of sound hypotheses, the recognition and measurement of sources of error, the criteria by which one theory is distinguished from another, repetition of experimental determination, and the use of averaging are all essential ideas that enable scientific knowledge to be distinguished from pseudo-science (Osborne, 1996, p. 56).

This would be the point where constructivist based instruction and inquiry-based instruction meet, overlap, and extend the instructional opportunities of students.
Inquiry/constructivist learning cycles.

Constructivists and learning theorists are convincing in their argument that only direct instruction has its flaws and Osborne and others have answered back that only hands-on activities are lacking as well. “Instead of pure discovery or pure direct instruction, students need strategic ‘scaffolds’ that embed instructional guidance in ongoing investigations to call attention to important decision points and to make data patterns more explicit” (National Research Council, 2007, p. 272). Bransford, Brown, and Cocking (2000) in How people learn: Brain, mind, experience, and school support the recommendation for structure and sequence of instruction:

An alternative to simply progressing through a series of exercises that derive from a scope and sequence chart is to expose students to the major features of a subject domain as they arise naturally in problem situations. Activities can be structured so that students are able to explore, explain, extend, and evaluate their progress. Ideas are best introduced when students see a need or a reason for their use—this helps them see relevant uses of knowledge to make sense of what they are learning (p. 139).

This is not a new idea. In the early 1960s Robert Karplus integrated Piaget’s ideas about child development and learning into a three phase cycle for learning science. The first phase was exploration, an opportunity to explore new materials and new ideas with minimal guidance, with the purpose of raising “questions or complexities that they cannot resolve with their accustomed patterns of reasoning” (Karplus, 2002, p. 75). This phase was followed by concept introduction which “starts with the definition of the new concept or principle that helps the students to apply a new pattern of reasoning to their experience” and concept application when “students apply the new concept and/or reasoning pattern to additional situations” (Karplus, 2002, p. 75). Atkin and Karplus
collaborated on a guided discovery model and called the above phases exploration, invention, and discovery (Atkin & Karplus, 2002). During the second phase of Karplus’ learning cycle Atkin added, “If the children are not able to invent the modern scientific concepts, it is necessary for the teacher to introduce the modern scientific concepts” (Atkin & Karplus, 2002, p. 84).

In 1991 Yager proposed a four phase learning sequence in his article “The Constructivist Learning Model”. He called his phases; invitation, exploration, proposing explanations and solutions, and taking action. During the invitation phase students ask questions, observe and note unexpected phenomena. When students are in the exploration phase they may be engaged in focused play, design a model, collect and organize data, or engage in debate. The third phase is when students propose explanations and solutions. This is when they communicate information and ideas, utilize peer evaluation, and integrate a solution with existing knowledge and experiences. The last phase, taking action, is when students apply their new knowledge and skills and ask new questions (Yager, 1991, p. 52).

In the mid-1980s Biological Sciences Curriculum Study (BSCS) expanded the learning cycle initially described by Atkin and Karplus into the BSCS 5E Instructional Model. The 5E model is based on the constructivist view that “….students redefine, reorganize, elaborate, and change their initial concepts through self-reflection and interaction with their peers and their environment” (Bybee, 1997, p. 176). Bybee (1996) adds:

the instructional model should (1) provide for different forms of interaction among students and between the teacher and students, (2) allow for a variety of
teaching strategies, such as inquiry-oriented investigations, cooperative groups, use of technology and (3) allow adequate time and opportunities for students to formulate knowledge, skills and attitudes (p. 46).

This model has five phases; engagement, exploration, explanation, elaboration, and evaluation. Engagement is when students focus on a problem or situation, they ask questions, or they are engaged in a discrepant event. “Successful engagement results in students being puzzled by, and actively motivated in, the learning activity” (Bybee et al., 2006, p. 9). The second phase is exploration, essentially the same as Atkin and Karplus’ first phase. “Exploration activities are designed so that the students in the class have common, concrete experiences upon which they continue formulating concepts, processes, and skills” (Bybee et al., 2006, p. 9). During the explanation phase “the teacher introduces scientific or technological explanations in a direct, explicit, and formal manner. Explanations are ways of ordering the exploratory experiences” (Bybee et al., 2006, p. 9). Elaboration is the fourth phase of the 5E model. This is the time that students are involved “in further experiences that extend, or elaborate, the concepts, processes, or skills. This phase facilitates the transfer of concepts to closely related but new situations” (Bybee et al., 2006, p. 10). Evaluation is the last phase of this model. During this phase students use their skills to evaluate their own understanding and they receive feedback on their explanations. Students are informally evaluated during all phases and formally evaluated during this evaluation phase. To date the BSCS 5E Instructional Model is used extensively in different curriculum models for students and for the professional development of teachers.
Magnusson and Palincsar envision the learning cycle somewhat differently than models discussed earlier. They “present a heuristic – a thinking tool – to support planning, enacting, and evaluating guided-inquiry instruction” (Magnusson & Palincsar, 2005, p. 427). Shown in Figure 1 it describes five phases as parts of a repetitive cycle that continues until the community comes to consensus about their knowledge claims. “This progression of events with the community knowledge claims resulting from each cycle is like threads that when woven together create the fabric of scientific knowledge and reasoning on the topic of study” (Magnusson & Palincsar, 2005, p. 461). The engage phase is designed to activate prior knowledge and to ask how students know it. Students also formulate a testable question during this phase for the first cycle of investigation. During the prepare to investigate phase students are deciding how to investigate their
question. What procedures will they use? What tools? “A critical aspect of preparing to investigate is determining with students what they will document and how during their investigation” (Magnusson & Palincsar, 2005, p. 435). They will also need to decide when they will know if they have enough data. During the investigate phase “students interact with the physical world, document their observations, and think about what these observations mean about the physical world” (Magnusson & Palincsar, 2005, p. 438).

Magnusson and Palincsar (2005) explain the interaction of content and process:

It may appear to students to be more about process because what we observe is a function of when, how, and with what tools we choose to observe. At the same time, what we observe is also a function of what we expect to observe, and how we interpret our observations is clearly influenced by what we already know and believe about the physical world (Magnusson & Palincsar, 2005, 439).

Another important aspect of the investigate phase is to provide feedback to students about the norms and conventions of scientific investigation, such as holding conditions the same, changing one variable at a time, and documenting observations so they are understood (Mathewson, 2005, p. 529). The next phase in the investigation cycle is prepare to report. This is when students are analyzing the data they have collected and looking for patterns, creating their knowledge claims just as scientist would.

In this phase, just as scientists use their laboratory documents to prepare papers for public presentation to the larger scientific community, students use the information and observations in their notebooks to prepare materials for public presentation to their classmates (Mathewson, 2005, p. 443).

The last, key phase of each cycle is reporting. This phase has two components, first to have small groups present their claims and evidence, then the “class discusses the commonalities and differences among the claims and evidence presented, noting claims that can be rejected, developing a class list of community-accepted claims, and
determining claims or questions that need further investigation” (Mathewson, 2005, p. 448). During the reporting phase because students are involved in discussion they become better at monitoring and questioning their own thinking (Donovan & Bransford, 2005, p. 569). This then leads to repeated cycles of investigation within the same context, building and refining students’ concept and science process understanding.

**Instructional Choices and Student Achievement**

The call for inquiry in the teaching of science has been echoing since before the time of Dewey. “We inquire when we question; and we inquire when we seek for whatever will provide an answer to a question asked” (Dewey, 1938b, p. 105). It resurfaced in the 1950s after Sputnik 1 was launched in 1957. Rutherford articulated the role of inquiry as early as 1964 (Rutherford, 1964) and again in 1990 as the Director of Project 2061 when he and Ahlgren wrote *Science for all Americans* reemphasizing the importance of inquiry in science education. Many science educators agree that inquiry/constructivist methods should provide the basis of science instruction (Aikenhead, 2006; R. D. Anderson, 2007; Atkin & Karplus, 2002; Bransford & Donovan, 2005; Bybee, 2006; Karplus, 2002; National Research Council, 2000; Osborne, 1996; Roth, 2006b; Rutherford & Ahlgren, 1990; Tobin & Tippins, 1993; Vasquez, 2008; von Glasersfeld, 1988; Yager, 1991).

But, the question remains, is inquiry/constructivist instruction more effective in increasing student achievement in science then more traditional instructional choices? The answer seems to be yes. In 1958 Atkin studied the effect of permissive classrooms, those that allowed students to fully participate in the inquiry process, and classrooms that
were more teacher-structured, less, permissive classrooms. He found that students in
more permissive classrooms were more likely to make original guesses instead of relying
on the authority of their teachers or materials. They also “employed empirical methods of
testing hypotheses significantly more than children in less permissive situations” (Atkin,
1958, p. 421).

In 1983 two meta-analyses were done looking at the effect of inquiry or activity
based science instruction. Bredderman (1983) did a meta-analysis of three major activity-
based elementary programs at the time, Elementary Science Study (ESS), Science – A
Process Approach (SAPA), and Science Curriculum Improvement Study (SCIS),
analyzing 900 classrooms. He found an overall effect size of 0.35 favoring the activity-
based programs and “32% of 400 studies favored activity-based program group and were
statistically significant at least the .05 level. Only 6% favored the non-activity-based
program group at the .05 level of significance” (Bredderman, 1983, p. 504). He also
found that disadvantaged students, those from lower socioeconomic, inner-city, rural, or
low ability, had a mean effect size of 0.65 compared to advantaged students who had a
mean effect size of 0.22. Disadvantaged students experienced an effect size of 1.00 on
process skills and an effect size of .52 on science content items.

Shymansky, Kyle, and Alport (1983) did a meta-analysis of 105 experiential
studies published after 1955 that compared new science curricula, those that emphasized
higher cognitive skills and integrated laboratory activities as processes of science, to
traditional curricula, those that emphasized knowledge of scientific facts and used
laboratory activities as verification exercises. They found that “students exposed to new
science curricula achieved 0.43 standard deviations above, or nearly one-half of a grade level, better than their traditional curriculum counterparts on general achievement measures” (Shymansky et al., 1983, p. 392). The highest effect sizes, 0.71, were reported in the categories of problem-solving and creativity. Techniques in process skills had an effect size (ES) of 0.61 and spatial relations had an ES of 0.57. They also noticed that the perceptions of students were more positive toward science than students exposed to traditional curricula with an ES of 0.50.

Atash and Dawson (1986), on the other hand, did a meta-analysis of research on the Intermediate Science Curriculum Study (ISCS) program. They found a very small positive effect of 0.09 overall and found that the ISCS group was outperformed in the achievement domain by traditional junior high science with an ES of -0.45.

In 1989 Glasson reported the effect of hands-on laboratory methods compared to teacher demonstration methods on student achievement and found that there was no difference in factual and conceptual knowledge between the two groups. He did however find that “students in the hands-on laboratory class performed significantly better on the procedural knowledge test than did students in the teacher demonstration class” (Glasson, 1989, p. 121). He found that “hands-on activities also promote peer interaction where students are free to argue, make mistakes, and challenge each other” (Glasson, 1989, p. 129). Stohr-Hunt (1996), on the other hand, used data collected by the National Education Longitudinal Study of 1988 (NEL:88) to analyze the effect of hands-on science experiences for eighth grade students on a standardized test of science achievement and found that “students who experienced hands-on activities frequently,
either every day or once a week, had significantly (<.001) higher scores of science achievement than those students who experienced hands-on science infrequently, once a month or less” (p. 105).

More than twenty years after Bredderman (1983) and Shymansky et al. (1983) conducted their meta-analyses, Schroeder, Scott, Tolson, Huang, and Lee (2007) conducted another meta-analysis of 61 research studies published between 1980 and 2004 on the effect of specific science teaching strategies on student achievement. Eight categories of teaching strategies surfaced during the analysis (effect sizes in parentheses): questioning strategies (0.74), manipulation strategies (0.57), enhanced material strategies (0.29), assessment strategies (0.51), inquiry strategies (0.65), enhanced context strategies (1.48), instructional technology (IT) strategies (0.48), and collaborative learning strategies (0.95). All of the effect sizes were significant, showing a “positive influence on student achievement when compared with the traditional teaching methods used in instruction of the control groups” (Schroeder, Scott, Tolson, Huang, & Lee, 2007, p. 1452). Traditional teaching methods were defined as “more teacher-dominated instruction with passive student participation” (Schroeder et al., 2007, p. 1444). Enhanced context strategies with an ES of 1.48 was identified as “strategies that relate learning to students’ previous experiences or knowledge or engage students’ interest through relating learning to the students’/schools’ environment or setting” (Schroeder et al., 2007, p. 1446), supporting the ideas about learning in How people learn (Bransford et al., 2000).

Schroeder and her colleagues (2007) go on to say:

If students are placed in an environment in which they can actively connect the instruction to their interests and present understandings and have an opportunity
to experience collaborative scientific inquiry under the guidance of an effective teacher, achievement will be accelerated (p. 1452).

**Inquiry-Based Science and Traditionally Underserved Students**

The intent of *Science for all Americans* and the NSES is that all students have access to high caliber science education. “The Standards apply to all students, regardless of age, gender, cultural or ethnic background, disabilities, aspirations, or interest and motivation in science” (National Research Council, 1996, p. 2). Bybee emphasizes this:

> It does not mean different objectives and different programs for particular individuals or groups of students. It does not mean a set of higher and lower, or harder and easier standards and experiences. Science for all implies the same standards for all, without exception (Bybee, 1997, p. 75).

The NSES “emphatically rejects any situation in science education where some people – for example, members of certain populations – are discouraged from pursuing science and excluded from opportunities to learn science” (National Research Council, 1996, p. 20).

Rodriguez (1997) wrote a critique of the NSES stating that the “invisibility discourse dangerously compromises the well-intended goals of the NRC by not directly addressing the ethnic, socioeconomic, gender, and theoretical issues which influence the teaching and learning of science in today’s schools” (p. 19). Lee and her colleagues point out that the NSES and *Science for all Americans* have defined science literacy, what counts as science, in the Western science tradition, not including, even excluding, contributions by the Egyptian, Chinese, and Arabic cultures (Lee, 1997, p. 219). The NSES and the AAAS may not have stated their intentions perfectly but the message is clear. The AAAS (1990) states emphatically:
When demographic realities, national needs, and democratic values are taken into account, it becomes clear that the nation can no longer ignore the science education of any students. Race, language, sex, or economic circumstances must no longer be permitted to be factors in determining who does and who does not receive a good education in science, mathematics, and technology. To neglect the science education of any (as has happened too often to girls and minority students) is to deprive them of a basic education, handicap them for life, and deprive the nation of talented workers and informed citizens – a loss the nation can ill afford (p. 214).

Kati Haycock in “Closing the Achievement Gap” stated that standards are the key to improving the educational opportunities of all students, particularly of students of poverty and of color (2001). In Dispelling the myth: High poverty schools exceeding expectations (1999) researchers from the Education Trust described the results of their study of 366 schools in 21 states that were high performing or most improved on state assessments and had over 50% of their students eligible for the federal lunch program (Barth et al.). They found that all schools included in the study were unusually focused on the high expectations found in state standards. These high-performing schools tended to “use state standards extensively to design curriculum and instruction, assess student work, and evaluate teachers; a full 80% of the high-performing, high poverty schools reported using standards to design instruction” (p. 2). They also found 94% of the 366 schools used standards to assess student progress. “These schools have become places where all classroom activity is aligned with the state standards” (p. 4).

In Bredderman’s (1983) meta-analysis of three activity-based science programs, he found that “disadvantaged students derived greater benefits than other students” (p. 499) in using hands-on materials to learn science content. Disadvantaged students, lower socioeconomic, inner-city, rural, or students with low ability, had a mean effect size of
.65 compared to average students with an effect size of .30 and advantaged students with an effect size of .22. He reported a mean effect size of 1.00 for disadvantaged students on science process skills and an effect size of .52 on science content knowledge. More recently, Blanchard et al. (2010) found that at the middle level, guided inquiry-based instruction seemed to have had a stronger effect for students from high poverty schools than those from low poverty schools (p. 603). They go on to report that “students in guided inquiry-based instruction classrooms tended to outscore students in traditional verification classrooms and middle school students appeared to benefit more than high school students from inquiry-based instruction” (p. 606).

In a study by Kahle, Meece, and Scantlebury (2000) of Ohio’s statewide systemic initiative (SSI) they were looking at the science achievement of urban African American students. They compared students’ achievement of teachers who were trained in standards-based teaching practices such as students: needing to give reasons or information to support answers, talking with peers, asking questions, and repeating experiments to check results, with teachers who had not been trained as part of the SSI. Kahle and her colleagues used standards-based teaching practices while others have used the terms inquiry-based or reform-oriented teaching practices to mean the same thing (Le et al., 2006; National Research Council, 1996). Students whose teachers had been trained reported that their teachers used standards-based teaching practices more frequently than did students in the non-SSI classes and they scored higher on the science achievement test (p. 1034). “Most importantly, the results of the correlational and HLM analysis indicated that students’ reports of standards-based teaching practices were important
correlates of science scores” (p.1034-1035). Other studies conducted in urban areas found that students involved in reform-oriented, inquiry-based instruction that was focused on state and national standards were more likely to show improvement on science assessments (Geier et al., 2008; Marx et al., 2004). Kanter and Konstantopoulos (2010) also found that minority students in urban middle schools engaged in project- and inquiry-based instruction had an achievement gain from pre- to post-test of 1.26 effect sizes. They note, “however, while there was improvement in minority student achievement overall, given that none of the post-test means reached a level of 3 [correct] or higher, there was still room for significant improvement in achievement” (p. 870).

In 1993 Sutman wrote *Teaching science effectively to limited English proficient students* for ERIC Clearinghouse on Urban Education based on earlier research. In it she described the elements necessary to teach science, in particular, to students who are still learning English. She points out that lectures and teacher demonstrations should be limited and should not be used to convey new information. Instead ELL students would be better served with “hands-on experiences that allow students to see and feel the meaning of words instead of just hearing the definitions” (p. 3). She goes on to say that the most effective strategy “for teaching science to LEP students is cooperative learning because it fosters language development through inter-student (and possibly written) communication” (p. 5).

In a discovery environment, students have the opportunity to find the answers to the questions they themselves pose about a topic. They develop their English language skills as they articulate the problems they have devised and their efforts to solve them, and they learn to learn on their own. Students should also be given ample opportunities to test their own ideas (Sutman, 1993, p. 6).
A number of studies have shown that not only the science achievement, but also the language acquisition of second language learners has benefited from inquiry-based instruction as described by Sutman (1993; Amaral, Garrison, & Klentschy, 2002; Bravo & Garcia, 2004; Buxton, 1998; Fradd, Lee, Sutman, & Saxton, 2001; Hampton & Rodriguez, 2001; Lee, Buxton, Lewis, & LeRoy, 2006).

Rodriguez and Berryman (2002) added to the discussion by advocating for Sociotransformative Constructivism (STC) for teaching science to students in diverse classrooms. They characterized STC as going beyond hands-on, minds-on activities by making science units authentic. “Students explore how the subject under study is socially relevant and connected to their everyday lives” instead of consisting of a collection “of entertaining hands-on activities” (p. 1021). Rodriguez and Berryman (2002) summarize that the STC approach not only increased students’ enthusiasm about scientific curriculum but also “significantly increased their knowledge, growth and understanding of science content” (p. 1042).

**Resources Needed for Effective Science Instruction**

Program Standard D of the *National science education standards* states:

The K-12 science program must give students access to appropriate and sufficient resources, including quality teachers, time, materials and equipment, adequate and safe space, and the community.

- The most important resource is professional teachers.
- Time is a major resource in a science program.
- Conducting scientific inquiry requires that students have easy, equitable, and frequent opportunities to use a wide range of equipment, materials, supplies, and other resources for experimentation and direct investigation of phenomena.
- Collaborative inquiry requires adequate and safe space.
- Good science programs require access to the world beyond the classroom. (National Research Council, 1996, p. 218)
The debate about the relationship between school resources and general student achievement has been going on for decades. Coleman et al. (1966) in their extensive survey, *Equality of educational opportunity*, found generally, that the relationship between school resources and student achievement are not large, but they are all in the direction of somewhat higher achievement: higher per pupil instructional expenditure, a curricula that offers greater challenges, more laboratories, and more activities [outside of the school day, but that] characteristics of facilities and curriculum are much less highly related to achievement than are the attributes of a child’s fellow students in school (p. 316).

Hanushek (1996), on the other hand, found in his vote counting meta-analysis that “the aggregate data provide a prima facie case that school spending and school resources are not linked to performance” (p. 51). Greenwald, Hedges, and Laine (1996), criticizing Hanushek’s methods, found “that a broad range of resources suggest that moderate increases in spending may be associated with significant increases in achievement” (p. 361). In 1966 Coleman et al. illustrating the idea that money counts, found for schools attended by Negros in the south high per pupil expenditure is associated with higher achievement at grades 6, 9, and 12. This result means that for Negroes in the south, achievement is appreciably lower in schools with low per pupil expenditure than in schools with high expenditure (p. 312).

Beese and Liang (2010) asked the question, “Do Resources Matter? PISA Science Achievement Comparisons between Students in the United States, Canada and Finland.” Finland was ranked first internationally on the PISA 2006 Science Literacy Assessment while the United States was ranked 21st. This study looked at how school resource indicators such as teacher qualifications and school resources affect science achievement. They found that Finland spends more money per pupil, at $6440, and “distributes it
centrally and equally, by per pupil allocation, to schools” (p. 269) then the United States which spends, nationally, only $5031 per pupil. Funding for schools in the United States is unequally distributed, depending on the state, the district, or even what part of town in which the school is located. Overall, school factors in Finland accounted for only 5.8% of the variance in students’ science performance while school factors in the U. S. accounted for 23.78% of the variance (p. 271). While school resource factors had little impact on science achievement in Finland, “. . . school type (private versus public), shortage of lab equipment, shortage of science teachers, and ratio of full-time versus part-time science teachers were significantly related to US and Canadian students’ science achievement” (p. 272), indicating that school resources do matter. Ceci, Papierno, and Mueller-Johnson (2002) suggest a new metaphor, where “certain departments of a hospital require disproportionately more resources than others in order to be successful because they deal with problems that are more severe” (p. 477).

As mentioned above the most important resource in any classroom is a professional, skilled teacher, one who see students as capable (Elmesky, 2006) and one who feels capable and confident (Le et al., 2006) in both their content knowledge and their pedagogical content knowledge. Kanter and Konstantopoulos (2010) evaluated students’ science achievement with the levels of teachers’ science content knowledge (CK) and pedagogical content knowledge (PCK). They found that “average post-PCK and average post-CK were significantly correlated \( r(6) = .72 \)” (p. 868) and could predict minority students’ science achievement scores. Le et al. (2006) found that “students with teachers who had more experience teaching at grade level and had more confidence in
their science knowledge outscored their peers whose teachers had less experience and were not as confident in their science knowledge” (p. 69).

Time is a crucial for effective inquiry-based science instruction (National Research Council, 1996; National Research Council, 2007). Inquiry-based instruction requires time for preparing opportunities for students to engage in serious scientific investigations including: preparing materials, setting up activities, creating learning environments, and crafting engaging student experiences. The *NSES* goes on to advocate that students are allocated time in the school program for science every day, every week, and every year (National Research Council, 1996, p. 219).

“Nothing interferes with inquiry-based teaching more than lacking an adequate supply of instructional materials” (National Research Council, 2000, p. 149). Bybee (1997) conceded that when the goal of science education is scientific literacy that the science program will overall be more expensive, implying “changes in facilities, equipment, materials, and in the end, budgets in order to specifically help students achieve the standards” (p. 195). Bybee goes on to say that budgets also need to “include support for curriculum materials aligned with standards and support for professional development” (197, p. 195). Coleman (1966) found somewhat higher achievement with “curricula that offers greater challenges, more laboratories, and more activities” (p. 316). Le et al. (2006) noted, “Greater access to science tools is associated with better multiple-choice and open-ended performance. Students with greater access to equipment and resources have more opportunities to participate in activities that foster scientific understanding” (p. 69). Generally, it’s agreed, effective reform-oriented, inquiry-based
science teaching depends on the availability of quality teachers, time to conduct investigations, materials, equipment, and technology (Bybee, 1997; Darling-Hammond, 2010; Kulm, Roseman, & Treistman, 1999; National Research Council, 1996; Vasquez, 2008).

**Professional Development for Science Teachers**

The goal of the reform movement in science in the 1990s was to improve science literacy and science learning for all students, but “reforming science education requires substantive changes in how science is taught, which requires equally substantive change in professional development practices at all levels” (National Research Council, 1996, p. 5). In order to change practices in science education to create changes in what and how students learn science, a strong professional development plan is necessary (Bybee, 1997; Loucks-Horsley, 1996; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010; National Research Council, 1996; National Research Council, 2000; National Research Council, 2007) which is not inexpensive.

An important focus of professional development for reform-oriented, inquiry-based teaching is the opportunity for teachers to *do* inquiry, both as a learning outcome for teachers in its own right, but also to improve teachers’ understanding of science content and pedagogy (Haefner & Zembal-Saul, 2004; Loucks-Horsley, 1996; National Research Council, 1996; National Research Council, 2000). “People teach as they are taught. Therefore, engaging in active learning, focusing on fewer ideas more deeply, learning collaboratively are all principles that must characterize learning opportunities for adults” (Loucks-Horsley et al., 1998; Loucks-Horsley et al., 2010). These opportunities
allow teachers to build their knowledge and skills, to think scientifically, and to reflect on what help their students might need to develop inquiry skills (Loucks-Horsley et al., 1998; Loucks-Horsley et al., 2010; National Research Council, 2000; National Research Council, 2007). Yager (1991) cautions that “in-service, whenever possible, must model but not mimic the strategies and ideas being advanced” (p. 57).

To be an effective teacher one needs to have accurate subject matter knowledge combined with pedagogical content knowledge (Kanter & Konstantopoulos, 2010; Lee & Luylex, 2007; Loucks-Horsley et al., 1998; Magnusson & Palincsar, 2005; National Research Council, 1996; National Research Council, 2007; Vasquez, 2008). Magnusson and Palincsar (2005) explain it this way

... teachers must have sufficient subject matter knowledge, including aspects of the culture of science that guide knowledge production, to fully understand the nature of the learning goals. Pedagogical content knowledge includes knowledge of the concepts that students find most difficult as well as ways to support their understanding of those concepts (p. 467-468).

Numerous studies have reported gains in students’ science achievement especially underserved students, both in content knowledge and process skills, with teachers who have participated in inquiry-based professional development (Banilower, 2002; Blanchard, Southerland, & Granger, 2009; Buczynski & Hansen, 2010; Kanter & Konstantopoulos, 2010; Lee, Maerten-Rivera, Penfield, LeRoy, & Secada, 2008; Wenglinsky, 2000; Zozakiewicz & Rodriguez, 2007).

In addition to teachers being involved in inquiry as professional development, it’s important for teachers to be part of a community of teacher-learners that “mirrors scientific communities” (National Research Council, 2000, p. 91), one that is
collaborative in nature. *NSES* describes the importance teachers working together, “some of the most powerful connections between teaching and learning are made through thoughtful practice in field experiences, team teaching, collaborative research or peer coaching” (National Research Council, 1996, p. 67). Collaborative teams have been described as groups with a common purpose, supporting one another, providing feedback, coaching and building their knowledge and confidence (DuFour & Eaker, 1998; Loucks-Horsley et al., 1998; National Commission on Mathematics and Science Teaching for the 21st Century, 2000; National Research Council, 2001; National Research Council, 2007; Reeves, 2003; Vasquez, 2008). Of course, professional development that consists of inquiry in a collaborative environment requires adequate time, resources, and commitment (Lee & Luylex, 2007; National Research Council, 1996; National Research Council, 2007).
Chapter Three: Methodology

Introduction

The purpose of this study is to describe the science instructional practices of a K-8 school that has consistently outperformed other schools in Colorado on the eighth grade science CSAP and has a population of traditionally underserved students. This study addresses the question:

What are the instructional choices, classroom environments, interventions, and school practices in place in one K-8 school that is supporting traditionally underserved populations of students in the learning of science?

Research Design

This study followed a descriptive mixed method case study approach to explore how one K-8 school in Colorado that had more than 20% ethnic minority and more than 25% of their students living in poverty was teaching and supporting the learning of science. Creswell and Plano Clark (2007) state that “mixed methods research provides more comprehensive evidence for studying a research problem than either quantitative or qualitative research alone” (p. 9). With this thought in mind this case study collected data from teacher surveys, a follow up teacher interview, two principal interviews, district and classroom curriculum documents, and classroom observations during four site visits. This study collected data from a variety of sources in order to “develop converging lines of inquiry, a process of triangulation and corroborate” (Yin, 2009, p. 115). Figure 2
illustrates how the various data sources came together to build an understanding of the school within the context of the district and the state. Each classroom, each school does not operate in a vacuum, accountable to only itself any more. A classroom is set within a certain school, which is then set within a district, and ultimately each district is set within a state.

Figure 3 details the elements that were explored to create the portrait of School D and the instruments used to collect the necessary data. One of the elements of a strong science program is its science curriculum and how well that curriculum is anchored on a foundation and aimed toward a recognized set of standards. Colorado does not have a state science curriculum. It does, however, have a set of standards that details what students should know and be able to do, and every fifth, eighth, and tenth grader in the
state is required to take the CSAP and be proficient on that state assessment. Research has shown that schools that are laser focused on common goals outperform schools that are not (Fullan et al., 2006; Reeves, 2002; Schmoker, 1996; Schmoker, 2001; Schmoker, 2006). To describe the science curriculum in the study school, School D, the researcher created the Analysis Protocol for Curriculum Documents (Appendix E) that shows the expected science content taught at each grade level, Kindergarten through fifth grade and every quarter for sixth grade through eighth grade throughout the district. This was then compared to the Colorado model content standards: Science (Colorado

<table>
<thead>
<tr>
<th><strong>Elements of School D Under Study</strong></th>
<th><strong>Data Collection Instruments</strong></th>
</tr>
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| Science Curriculum: Alignment and Articulation | ➢ Analysis Protocol for Curriculum Documents  
➢ RAND Survey  
➢ Classroom Observations  
➢ Classroom curriculum documents |
| Resources Allocated for Science Instruction | ➢ RAND Survey  
➢ Principal Interviews  
➢ Site Visit  
➢ Classroom Observations  
➢ Analysis Protocol for Curriculum |
| Professional Development | ➢ RAND Survey  
➢ Principal Interviews  
➢ Teacher Interview |
| Classroom Environment  
➢ Teacher Background  
➢ Instructional choices  
➢ Student – Student Interactions  
➢ Teacher – Student Interactions | ➢ RAND Survey  
➢ CLES 2(20) Survey  
➢ Classroom Observations  
➢ Essential Features of Classroom Inquiry |

Figure 3. Chart listing data collection instruments used to describe elements of School D.
Department of Education, 2007) to identify how closely the district curriculum and pacing guides were aligned with state standards. To assess whether the district curriculum was implemented with fidelity teachers reported what units they taught during the year on the RAND survey, between two and three classroom observations were made of each class, and classroom curriculum documents were collected.

The teacher is the catalyst for the classroom. The decisions that the teacher makes can make or break a year of instruction for students. The National science education standards (NSES) begins with standards for the teaching of science, including planning of inquiry-based science, facilitating learning, and designing learning environments that enable students to learn science (National Research Council, 1996, p. 4). Since scientific investigations can range from highly structured, cookbook oriented, where the question and the outcome are known before hand to open, free-ranging explorations, where the problem, as well as the method and the conclusion are left open (Herron, 1971; National Research Council, 1996; National Research Council, 2007; Roth, 2006a) observations of the classroom environment were important to discover what experiences science classrooms in School D offer students. To that end data were collected using the RAND survey (see Appendix C) and between two and four classroom observations were made of each class which included completing the Essential Features of Classroom Inquiry (see Appendix G) from Inquiry and the national science education standards (National Research Council, 2000, p. 29). Another aspect of a science classroom akin to inquiry is that the learner is constructing their own meaning of science within a social structure (R. D. Anderson, 2007; Dewey, 1938a; von Glasersfeld, 1993; Vygotsky, 1962; Yager, 1991)
or constructivist learning. The CLES 2(20; see Appendix C) was selected to evaluate the degree of constructivism in the classroom because it is shorter by ten questions but has the same reliability (Johnson & McClure, 2004) as the original Constructivist Learning Environment Survey (CLES) developed by Taylor, Fraser, and Fisher (1997). The data from the classroom observations were used to corroborate the self reported CLES 2(20).

NSES Program Standard D advocates that a “K-12 science program must give students access to appropriate and sufficient resources, including quality teachers, time, materials and equipment, adequate and safe space, and the community” (National Research Council, 1996, p. 218). There is some debate about the relationship between school resources and general student achievement. Coleman, et al (1966) and Greenwald, Hedges, and Laine (1996) found that an increase in spending could lead to an increase in student achievement. Hanushek (1996), on the other hand, found that spending was not linked to higher student achievement. To identify the resources available for School D, data from the RAND survey, the two principal interviews (see Appendix D), the site visit (see Appendix F), and the classroom observations were compiled. The Analysis Protocol for Curriculum was used to match up curriculum with materials available.

Professional development is a critical component of reforming science education. In order to change how science is taught, making it more inquiry/constructivist is nature, there needs to be a strong professional development plan (Bybee, 1997; Loucks-Horsley, 1996; Loucks-Horsley et al., 1998; Loucks-Horsley et al., 2010). “Professional development that supports instructional improvement rests on school – and system – level commitments that are manifested in actively involved leadership” (National Research
Council, 2007, p. 346). Professional development needs to be ongoing and embedded in the teacher’s work, not a scatter-shot approach. The professional development plan for School D and the district was assessed using the RAND survey, the two principal interviews, and the follow-up teacher interview (see Appendix D).

Each classroom does not operate in a void; it is set within a school, so in order to understand the classroom it’s important to understand the context, the school. In order to understand School D, a site visit was made and the School Observation Protocol (see Appendix F) used to identify the demographics of the school, the number of teachers and hours of instruction, and what interventions to which students might have access. The two principal interviews and the follow-up teacher interview were also used to gain an understanding of the school context.

Participants and Site

A three-stage screening procedure was used to choose which middle schools to include in the study pool, and from that School D was ultimately chosen as the study school. The CSAP was used as an indicator of the level of students’ proficiency in science inquiry and science content. The CSAP is tightly aligned with state standards through processes whereby teachers worked to match assessment questions with each particular benchmark in item review sessions. Since the beginning of the science CSAP in 2000 inquiry process skills has been a primary focus of the CSAP with 40% of the questions directly assessing inquiry skills. Students are given scenarios in which they need to determine what questions the students in the scenario might be asking, what hypothesis they might be testing for example. Students write conclusions, create graphs
and then extrapolate from data. CSAP results are therefore a legitimate tool for selecting the study school.

The first step was to analyze the 2009 CSAP results for the eighth grade science CSAP to determine which middle schools had the percentage of students performing proficient or above at or above the 75th percentile compared to the state average for eighth graders. Unfortunately, most of the top performing schools in the state were also schools made up predominately of White students who do not receive free/reduced lunch support which furthers an achievement gap in science in Colorado. To further narrow the study pool it was important to find schools that had a sizeable population of traditionally underserved students. Of 67 middle schools meeting the first criterion, there were only five schools with a large enough percent of underserved students and who were also performing well on the eighth grade Science CSAP.

The percent of the school population that qualifies for free or reduced lunches has been a part of the district/school CSAP report since 2003. These five schools were found to have approximately 25% or more students that qualify for the federal meal program and approximately 20% or more students belonging to an ethnic/racial minority, less than Title I requirements. This data was pulled from the Fall 2008 Pupil Membership by District, School, Grade, Race/Ethnicity, and Gender report (Colorado Department of Education). This same process was repeated with CSAP and Pupil Membership data from 2006 through 2008. Sixty-seven middle schools were at or above the 75th percentile while only five schools; School A, School B, School C, School E, and School F met the criteria of having enough underserved students to be included in the study pool. The other
sixty-two middle schools had more than 80% White students and fewer than 25% of their students were receiving free/reduced lunches; this is the demographic expected to do well on any standardized test of academic achievement.

The third stage was to analyze the Science CSAP data from 2009 for ethnic minorities and students receiving free/reduced lunches for each of the five middle schools meeting the initial criteria. School E and School F were eliminated from the study pool because School E had fewer than sixteen students in each of the disaggregated categories so no percentages were reported and School F only had data on their Hispanic population and students qualifying for free lunch. Only twelve percent of their Hispanic students and fourteen percent of their poverty students scored at the proficient or above level.

While analyzing the Science CSAP for disaggregated ethnic and free/reduced lunch data, it was discovered that School D had exceptionally high performance for students in three groups; Hispanic students, Black students and students eligible for free lunch, on the 2009 Science CSAP. Table 5 shows that School D did not meet the initial

Table 5

Schools with at least 20% Ethnic Minority and at least 25% Free-Reduced Lunch Performing at or above the 75th Percentile on the Science CSAP

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>School A</td>
<td>District 1</td>
<td>82</td>
<td>91</td>
<td>74</td>
<td>81</td>
</tr>
<tr>
<td>School B</td>
<td>District 2</td>
<td>80</td>
<td>82</td>
<td>73</td>
<td>69</td>
</tr>
<tr>
<td>School C</td>
<td>District 3</td>
<td>73</td>
<td>60(^a)</td>
<td>68</td>
<td>70</td>
</tr>
<tr>
<td>School D</td>
<td>District 4</td>
<td>44(^a)</td>
<td>58(^a)</td>
<td>71</td>
<td></td>
</tr>
</tbody>
</table>

Note. Data for this table was retrieved from the Colorado Department of Education, Unit of Student Assessment Website, December 30, 2009

\(^a\)Did not meet all three criteria that year
criteria until the 2009 CSAP, however, the school showed considerable gains in the percent of students performing proficient or above at the eighth grade level since 2007.

Table 6 shows the disaggregated data for School A, School B, School C and School D for the Science CSAP from 2009. Hispanic students at School A performed in the 95th percentile compared to other schools with Hispanic, Black, and American Indian students statewide, the only category with sixteen students or more. Hispanic students at School B performed in the 90th percentile compared to other schools with Hispanic, Black, and American Indian students statewide and students eligible for free lunch performed above the 80th percentile compared to other schools with students eligible for free/reduced

Table 6

2009 Disaggregated Data for Schools with at least 20% Ethnic Minority and at least 25% Free-Reduced Lunch Performing at or above the 75th Percentile on the Science CSAP

<table>
<thead>
<tr>
<th>2009</th>
<th>State</th>
<th>District 1</th>
<th>School A</th>
<th>District 2</th>
<th>School B</th>
<th>District 3</th>
<th>School C</th>
<th>District 4</th>
<th>School D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>49</td>
<td>60</td>
<td>81</td>
<td>49</td>
<td>69</td>
<td>53</td>
<td>70</td>
<td>53</td>
<td>71</td>
</tr>
<tr>
<td>White</td>
<td>61</td>
<td>67</td>
<td>89</td>
<td>58</td>
<td>72</td>
<td>77</td>
<td>86</td>
<td>59</td>
<td>71</td>
</tr>
<tr>
<td>Hispanic</td>
<td>25</td>
<td>31</td>
<td>56</td>
<td>29</td>
<td>48</td>
<td>34</td>
<td>54</td>
<td>23</td>
<td>71</td>
</tr>
<tr>
<td>Black</td>
<td>25</td>
<td>37</td>
<td>a</td>
<td>24</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>23</td>
<td>76</td>
</tr>
<tr>
<td>Asian</td>
<td>60</td>
<td>65</td>
<td>a</td>
<td>59</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>42</td>
<td>a</td>
</tr>
<tr>
<td>American Indian Reduced Lunch</td>
<td>35</td>
<td>43</td>
<td>a</td>
<td>51</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>45</td>
<td>a</td>
</tr>
<tr>
<td>Reduced Lunch</td>
<td>26b</td>
<td>46</td>
<td>a</td>
<td>38</td>
<td>a</td>
<td>51</td>
<td>a</td>
<td>38</td>
<td>a</td>
</tr>
<tr>
<td>Free Lunch</td>
<td>28</td>
<td>a</td>
<td>27</td>
<td>43</td>
<td>26</td>
<td>a</td>
<td>21</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>Not Free/Reduced Lunch</td>
<td>61</td>
<td>69</td>
<td>83</td>
<td>63</td>
<td>74</td>
<td>65</td>
<td>76</td>
<td>51</td>
<td>67</td>
</tr>
</tbody>
</table>

Note. Data for this table was retrieved from the Colorado Department of Education, Unit of Student Assessment Website, January 30, 2011.

aLess than 16 students in population group. bState reported Free/Reduced Lunch together
lunch. Hispanic students at School C also performed in the 95th percentile compared to other schools with Hispanic, Black, and American Indian students statewide. Hispanic students and Black students at School D outperformed all other schools with Hispanic, Black, and American Indian students statewide and students eligible for free lunch outsourced students not eligible for free or reduced lunch at School D and all other schools statewide that had students eligible for free lunch. All four schools outperformed the state and their respective districts in each category with sixteen or more students.

One concern was the limited number of case sites and by extension the number of students and teachers possibly included in this study. In analyzing the CSAP data, the CDE Fall membership reports, the ethnicity, and free/reduced lunch data, the pool of case sites chosen were the only middle schools in Colorado meeting the criteria out of the 67 schools that had students performing at or above proficient in the 75th percentile. The four schools chosen to be part of the pool accounted for less than 1% of all Colorado eighth graders in 2009, a negligible percentage. Of the four schools, only School B had over 100 eighth graders at 219 in 2009. School A had 93 eighth graders in 2009 while School C had 56 and School D had 63. The value of this descriptive case study is to identify school and classroom practices, on a small scale, that are working toward successfully teaching science to all their students regardless of each student’s classification. Hamilton et al. (2003) after analyzing a large-scale reform effort, National Science Foundation’s Systemic Initiatives, stated “that it might make sense to focus first on understanding what it takes to bring about changes in achievement on a small scale and then determine what
steps would be necessary to instill those changes more broadly” (p. 17) instead of starting with large-scale reform efforts.

In order to study a school as typical as possible that still had the diverse populations of interest, Hispanic students, African American students, and students eligible for federal lunch support, the decision was made to study School B. School B had the largest number of eighth graders, the target population of the Science CSAP, of the four schools. This more closely resembled other middle schools in the state. This school is part of a large urban school district which is where larger numbers of diverse students are located. The students at School B were performing better than the average at the state level, and had for four consecutive years, and students that make up diverse populations were outperforming Hispanic students and students of poverty statewide. There was still an achievement gap at School B, but in 2009 the difference in percent of students performing proficient or above was 24 percentage points while the state difference was 36 percentage points. School B has nine sixth through eighth grade teachers teaching both math and science, with two teachers teaching only eighth grade science for a total of eleven teachers relevant to this study. This was important in considering School B; the number of teachers allows for a broader picture of a school’s instructional practices, and therefore, it would be important for all teachers to complete the survey.

District 2 in which School B is a part chose not to participate in this study, so School D was considered. School D had a much smaller number of eighth graders and it only met the criteria in 2009, but it did make continuous gains in the percent of eighth grade students performing at or above proficient from 2007 with 44% to 58% in 2008 to
71% in 2009 and met the other criteria with the percent of ethnic minority students and the percent of students eligible for free/reduced lunch. The data in Table 7 shows that School D had essentially eliminated the achievement gaps between all groups of students. School D, a K-8, had eleven teachers teaching fifth grade through eighth grade students and 18 teachers at Kindergarten through fourth grade for a total of 29 teachers. It was very important at School D to get responses from all the teachers teaching science, again to get a clear picture of the practices that have been so successful in closing the achievement gap in this school. Permission was granted to conduct the study at School D by first the school’s district office, then the principal, and finally the teachers involved in teaching science.

The third school that was under consideration was School A. It was primarily a K-6 school, but students could choose in for seventh and eighth grade. In 2009 it had 93 eighth graders, second to School B. The only subgroup at School A, however, was made up of Hispanic students. They do not have a reportable number of students identified as free/reduce lunch recipients or other students of color. This school had two teachers teaching seventh and eighth grade science along with 35 Kindergarten through sixth grade self-contained classrooms. It would have been critical for both seventh and eighth grade teachers to respond to the teacher survey while a percentage of the K-6 teachers would have been acceptable. It would have been important to get a response from a range of grades in order to identify how the science program built as students progressed through this school, getting responses from at least two teachers at each grade would have been acceptable.
School C was the smallest middle school of the study pool with only 56 eighth grade students in 2009. Similar to School A, School C only has one subgroup of students, made up of Hispanic students. They also did not have a reportable number of students identified as free/reduce lunch recipients or other students of color. Since it was small it was very likely that only two or three teachers teach science to students in all three grades. It would have been very important to get responses from all teachers who teach science to get an accurate picture of instructional practices. Contact was made with the principal of School C and it was determined that the school had undergone a significant restructuring between 2009 and 2011, so a study of current practices could not be connected to success on the 2009 Science CSAP.

**Data Collection**

The researcher emailed the school principal introducing the study and asking for a time to talk on the phone in order to thoroughly explain the study and get permission to work with their school and to arrange to meet with teachers involved in science instruction (see Appendix A). After permission was granted by the principal, emails were sent to teachers who were teaching science third quarter, explaining the rationale for the study and the reason their school was picked, that they have had success with all students, particularly with less represented groups, and an initial meeting was set for the first school visit in order to conduct the initial interview with the principal and the first set of classroom observations.

At the beginning of the first school visit the researcher met with the principal of School D, explained the informed consent (see Appendix B), and conducted the first of
two interviews. Classroom observations were coordinated at the school site, so as to observe science instruction at grades three, five, six, and eight. The informed consent letters were reviewed with teachers for both the surveys and the classroom observations (see Appendix B) then the teacher surveys were given to teachers to complete on their own to be collected during another school visit.

In order to match classroom observations with survey responses the researcher needed to know participants’ names; names of participants are only on the signature page of the informed consent. However, the researcher has ensured confidentiality of teachers’ and the principal’s responses at the school site by using classroom numbers, 1, 2, 3, and 4, to refer to classrooms observed and the corresponding teacher instead of teacher names (e.g. teacher of classroom 1 or classroom 1’s teacher). The school will be identified by School D. The principal will be referred to as the principal of School D or School D’s principal. The study will be embargoed for a period of time.

Four school visits were conducted between January 12, 2012 and February 16, 2012 as part of the data collection process in order to create a description of the science facilities, the context of the science program, and the context of the educational experiences of ethnic minorities and students living in poverty. Observation protocols were used during the school site visit to provide information about the school’s curriculum, the school science facilities and the classrooms where science was taught. After the third visit to the school to make observation, it became necessary to create and conduct another interview with the principal and to interview the lead science teacher in order to answer questions that came up in early data analysis.
Instruments

In order to understand teachers’ teaching experience and background information, professional development, curriculum content for the academic year, and instructional choices a survey developed by Linda Hamilton and her team at the RAND Corporation to conduct the Mosaic II longitudinal study was adapted in order to generalize the questions and make it more applicable to teachers in Colorado (Le et al., 2004; Le et al., 2006; Stecher et al., 2002). Permission to adapt the Mosaic II surveys was granted through email contact with Linda Hamilton on August 19, 2008. This survey was chosen because of the uniqueness of the format. This survey incorporated the use of vignettes or scenarios to provide a context for teachers to indicate a variety of teaching strategies. “Teachers were provided with a set of options that indicated how they were most likely to respond in each situation. The options were designed to capture an array of responses, ranging from less reform-oriented to more reform-oriented behaviors” (Le et al., 2004). Responses include teacher lecture and use of textbooks and worksheets, less inquiry-based practices or more teacher-centered, to responses about engaging students in problem-solving in small groups and working on extended investigations, more inquiry-oriented practices or more student-centered. Teachers responded on a 4-point Likert scale from very unlikely to very likely in response to certain prompts given after the description of the scenario. There were two scenarios included in the survey asking similar types of responses within different science content foci. Both scenarios started with a question about how the teacher would introduce the topic of study. Then the survey asked how teachers might respond if students were showing misconceptions or
making a mistake in measurement. Next the survey asked how the teacher would respond to differing explanations by students. The last question of the survey asked the teacher to choose which unit learning objectives they would emphasize.

The RAND survey was also chosen because of the extensive background work on the validity of the scenarios. Three aspects of the validity of the vignettes from the original Mosaic II were measured, internal validity, external validity, and qualitative validity. Internal validity “results suggest that the vignettes were measuring relatively stable aspects of reform-oriented teaching” (Le et al., 2006, p. 44). In regard to external validity, Le and colleagues (2006) noted that

the empirical analyses provide some qualified support of the validity of vignettes as indicators of reform-oriented instruction. The item-level analysis and the patterns of correlations among the problem-level scores suggest that reform-oriented teaching is a stable aspect of teacher’s instruction (p. 45).

To measure qualitative validity, Le et al. conducted cognitive interviews with 30 teachers which indicated “that teachers’ understanding of vignettes and the options matched our own. In 84 percent of the cases, teachers’ interpretations of vignette items agreed with our intentions” (2006, p. 46). In addition to the vignettes the survey gathered data about hours of science instruction, materials available, how often teaching strategies were used, how often students were engaged in differing learning activities, curriculum coverage, and teacher background, including experience, degrees, and professional development for the purpose of describing science instruction and resources in each school (See Appendix C).

The original RAND Mosaic II survey was written to study a specific reform effort. The surveys were written specifically for six different grade levels over three
years. The first year of the study, the surveys were written for third and sixth grade. The next year the surveys were sent to fourth and seventh grade teachers and in the last year surveys went to teachers of fifth and eighth grade, attempting to follow a group of students and the instructional strategies to which they were exposed (Le et al., 2006). In order for teachers of different grades to complete the same survey, the Mosaic II surveys were adapted into one survey. The directions for each section were taken from the original surveys. In the section asking about professional development, the original seven items were retained and two items were added, asking about the hours of professional development in strategies for teaching traditionally underserved student populations, since the numbers of diverse students continues to rise, and the numbers of hours for the opportunities for collaborating with peers, team teaching, or peer coaching, a key component of effective and substantive change in practice (Bybee, 1997; Loucks-Horsley et al., 2010; National Research Council, 1996; Vasquez, 2008).

In the section about curriculum the question asking about time spent teaching specific units was made open-ended since each grade would teach different units. This could then be compared to the Analysis Protocol for Curriculum Documents. The original Mosaic II was very specific about the units taught at each grade. The questions about the use of the Science Sleuths program were deleted from this study’s survey. The other change made in the curriculum section was the question asking about availability of tools and materials; the list was created with what each grade might need to meet the state standards.
Each Mosaic II survey had two scenarios which were different at each grade level. In adapting the Mosaic II surveys for this study, the general directions for the scenarios were kept the same. The directions and questions for the two chosen scenarios were also kept the same. The scenarios chosen for this study were Scenario 1: Springs and Scenario 2: Heredity and Punnett Squares, one topic from physical science and one from life science. The Springs scenario was focused on variables and measurement while the Heredity scenario supports a focus area in the state science standards. The teacher background questions were kept the same except two questions on the original surveys that asked about Master Science Teacher or Science Resource Teacher for MCPS Science Connections project were rephrased and just asked if the teacher had ever served as a lead teacher in science.

In order to assess the perceptions of classroom teachers in the study about how constructivist or student-centered their classroom environment was a revised Constructivist Learning Environment Survey (CLES; Aldridge, Fraser, Taylor, & Chen, 2000; Johnson & McClure, 2004; Taylor et al., 1997) named CLES 2(20) was used. Taylor (1997) stated that a “major advantage [of the CLES] is the enhanced viability that allows it to be used across a range of ‘grain sizes’, from case studies of individual classrooms to state-wide reform initiatives” (p. 300). The five original scales of the CLES were retained; personal relevance, how connected school science is to student’s out of school experiences, uncertainty, opportunities for students to experiencing the changing nature of science, critical voice, culture in which students feel safe in questioning the plans and methods, shared control, students share control of the learning environment,
and student negotiation, opportunities for students to explain and justify their ideas to other students (Taylor et al., 1997, p. 296). The numbers of items in each scale were reduced from six to four and maintained its validity and reliability (Johnson & McClure, 2004). The CLES 2(20) asked teachers to respond to statements about activities in their science classrooms on a 5-point Likert scale, ranging from almost always to almost never (See Appendix C).

An open-ended interview questionnaire was designed by this researcher and used to interview the school principal. The interview started with a general question asking the principal to what they might attribute the school’s achievement levels. The next set of questions asked about resources; effective use of time in the schedule, how Hispanic and African American students and students of poverty are represented in higher level math and science classes framed from Jane Butler Kahle’s article “Equitable Systemic Reform in Science and Mathematics: Assessing Progress” (1998) and what supports were available from the district. The next set of questions asked two questions about what interventions are available for students both in science specifically and other areas (i.e. math and literacy). Most of the interview questions were about professional development. Designing professional development for teachers of science and mathematics (Loucks-Horsley et al., 2010) was used to frame questions about how professional development has been utilized to improve the science performance of students (See Appendix D), questions about school and district science leaders, opportunities for collaboration, and how data were shared across the school community. A second interview became necessary when information was needed about the science budget, specifically science
equipment, consumable science supplies, and supporting resources from the district, about more current CSAP data, and about the principal’s perceptions on the uniqueness of the eighth graders in 2009 (see Table 7 in the School Context section of the Results).

Observation protocols were developed to collect data from curriculum documents (see Appendix E), the school visit/tour (see Appendix F), and classroom observations (see Appendix G). Since there is no state science curriculum only state standards the Analysis Protocol for Curriculum Documents was used to identify the science content that was emphasized by the district at each grade level, kindergarten through eighth grade, the sequence of instruction within one school year at the middle level, by quarter, and the articulation of content from one year to the next. One ideal for content and articulation that many states, including Colorado, have used to develop state standards is *Benchmarks for science literacy* (American Association for the Advancement of Science, 2009) which was developed based on the ideas expressed in *Science for all Americans* (Rutherford & Ahlgren, 1990). This was then used to compare the district expectations to both the classroom instruction and *Colorado model content standards: Science* (Colorado Department of Education, 2007) to determine if the school and district curriculum were aimed directly at the target, state science standards.

Observations of the school in general were recorded on the School Observation Protocol. Originally the School Observation Protocol only asked for student demographics, information about the number of science teachers, the schedule, and intervention classes, but it was quickly clear that that was too limited for the scope of the school visit/tour. Notes were then made of observations in the science preparation room.
between the two science classes, the empty science classroom, looking for specific science resource materials. In order for science instruction to be predominately inquiry-based with students conducting their own investigations, they need high quality, appropriate tools and materials (Bybee, 1997; Elmesky, 2006; Le et al., 2006; National Research Council, 1996; Vasquez, 2008). The hallways and the media center were toured looking for science related materials in areas other than classrooms.

Classroom observations were made on the Classroom Observation Protocol. It included identifying information; teacher number, grade, and number of students in the class. During one observation period counts were made of boys compared to girls and ethnic/racial minority students compared to students who were not minority students. Date and time of the observation were also noted on the observation form. The researcher noted the science content focus of the lesson and recorded a general description of the classroom activities. Additional notes were taken to describe classroom climate, the teacher’s instructional style, how teachers interacted with students, and how students interacted with each other. Using the Essential Features of Classroom Inquiry and Their Variations (National Research Council, 2000)) the extent that each classroom was focused on inquiry instruction and whether it was more student-centered or teacher-centered was identified. The Essentials Features of Classroom Inquiry was chosen specifically to focus the researcher during a classroom observation on the key components of an inquiry lesson; the learner engages in scientific questions, gives priority to evidence, formulates explanations from the evidence, connects explanations to scientific knowledge, and communicates and justifies explanations. The classroom
observation protocol was used to corroborate data from the Analysis of Curriculum Documents, the RAND survey, the CLES 2(20), and the principal interviews. Over all twelve classroom observations were made. The collective data were analyzed to create a picture of each classroom and a collective picture of science classrooms across the school, looking for student-centered teaching compared to teacher-centered teaching.

As data were collected at School D it became important to try and ascertain what was going on during school year 2008-2009 and before compared to what happened after 2009. On the Science CSAP in 2009 eighth graders scored exceptionally well with no gaps between disaggregated groups. On the Science CSAP in 2010 the percent of all eighth graders scoring proficient dropped 24% and the gaps between White students and other groups ranged between 30% and 43%. In 2011, the percent of all eighth graders scoring proficient dropped another 9% with White students’ scores decreasing by 29%. The researcher created a Teacher Follow-up Interview Questionnaire asking the teacher about how her work as the teacher leader and her work with the district science coach had changed, how her specific instructional day had changed, and what might have been unique about the 2008-2009 eighth graders. The teacher chosen to interview was both the science teacher leader at School D, but was also an eighth grade science teacher over the five year period in question.

Analysis

Le et al. (2004) Le et al. (2006), Hamilton et al. (2003) and Stecher et al. (2006) from the RAND Education organization in their research used the term reform-oriented instruction to identify instructional strategies that are more student-center rather than
teacher-centered, more in keeping with the call for reform in science education. Kahle, Meece, and Scantlebury (2000) used the term standards-based instruction to identify those practices that are more student-centered and inquiry-based. Most of the literature, however, refers to inquiry-based practices or inquiry-based instruction to describe behaviors that are more student-centered in keeping with the NSES’ description of inquiry where students: ask testable questions, determine the needed evidence, construct explanation, and communicate their new understandings (Abrams, Southerland, & Evans, 2008; Anderson, 2007; Bybee, 2006; Dewey, 1938; Magnusson & Palinscar, 2005; NRC, 1996; NRC, 2000; NRC, 2007; Roth & Bowen, 1995; Roth, 2006; Rutherford, 1964; Rutherford & Ahlgren, 1990). This paper will use inquiry-based or inquiry-oriented to mean reform-oriented or standards-based instruction or instructional strategies.

The RAND teacher survey was analyzed using two different methods. All questions were analyzed first using SPSS 12.0 for Windows for measures of central tendency, standard deviation, and variance; however, that data didn’t inform the picture of each science classroom. The analysis of central tendency pertaining to professional development, teacher background and experience, and questions about teaching strategies in general were useful in getting an overall picture of the school and a glimpse of the culture of inquiry-based instruction. The eight scenario questions of the RAND survey that ascertained the extent of inquiry-oriented instruction were first grouped by introductory activity choices, response to student error choices, differing explanation choices, and emphasis on the specific learning objectives choices. Each group was then analyzed by calculating a simple mean of response choices for inquiry-oriented choices.
compared to other, less, inquiry-oriented choices. These data then became part of the story of each classroom. The CLES 2(20) survey was first grouped by scale; personal relevance, uncertainty, critical voice, shared control, and student negotiation and each scale was analyzed by calculating a simple mean of response choices within each scale and then a mean of the total overall was calculated.

QSR NVivo 9 is the latest iteration of what started as NUD*IST, a software program that compiles and organizes large quantities of qualitative information. *Qualitative data analysis with NVivo* was used to work through the NVivo program and analyze the qualitative data (Bazeley, 2007) from this study. Nodes were created for instructional practices, each of the inquiry processes from the Essential Features of Classroom Inquiry and a node for not inquiry, each of the scales from the CLES, the different forms of resources, each class was a separate node, as was the principal, the school, the district science coach, and professional development. Aligned content, experiments, and science note-booking were also nodes. As data were analyzed additional nodes were created for 2009 and earlier, after 2009, trust, and distrust. NVivo allowed for the same entry to be coded into multiple nodes so that understanding about each node/concept could be built from different documents and relationships could be discerned. The researcher generated queries of intersecting nodes in order to drill down to specific data. This was very helpful when describing each of the Essential Features of Classroom Inquiry and each of the CLES scales for each classroom. Professional development was also analyzed this way, discerning professional development related to
traditionally underserved students, confidence of teachers, and district science coaches for example.

The initial principal interview was rewritten from notes made during the interview and uploaded into NVivo where they were coded into nodes in order to splinter and recombine information from different data documents. Some of the nodes that the principal interview was coded into were aligned content, interventions, diversity, time, after 2009, professional development, and district science coach. The principal follow-up interview asked about the budget, so those responses were coded into resources, materials, and budget. It also asked questions about the principal’s perception of the change in 2009, there were codes for 2009 and earlier, professional development, and district science coach.

The Analysis Protocol for Curriculum was uploaded into NVivo as well as the district pacing guides for quarter three for sixth grade and eighth grade and the *Colorado model content standards: Science* (2007). Entries were sorted into nodes for each class, 1 through 4, aligned curriculum, instructional practices, 2009 and earlier, after 2009, resources, and FOSS kits. The School Observation Protocol, each classroom observation, and the teacher follow-up interview were all uploaded and coded in the same manner described above.

Each classroom was treated as a mini case study, looking at the classroom environment in place in each classroom in the school under investigation and the extent to which inquiry-based or constructivist instruction was being used school wide. Using NVivo a comparative analysis was done to fully understand the school as a whole (See
Figure 3. “After each case is well understood (the cross-cutting variables may evolve and change during this process) you ‘stack’ the case-level displays in a ‘meta-matrix,’ which is then further condensed, permitting systematic comparison” (Miles & Huberman, 1994, p. 176). The aim was to identify similarities between classrooms. Practices that were unique to each may also appear in the analysis. From this view it was possible to generalize common practices in science instruction to the school as a whole. Then, all data from all sources was compiled to formulate an in-depth picture of School D.

**Limitations**

Limitations of the RAND survey in the Mosaic II study included no control of the assignment of students to teachers; possible tracking of students, and more extensive
classroom observations might have improved the vignettes (Le et al., 2006). Le et al. (2006) suggest that stronger conclusions on the Mosaic II could be made if they used an experimental design instead of using “naturally occurring variation in exposure to reform-oriented instruction” (p. 71). These limitations could also affect this case study. Even though the Mosaic II survey and the CLES 2(20) were used in the past with thousands of teachers in order to validate the instruments, they have not been used in Colorado case study research with a very limited numbers of teachers. Different results are possible with the small sample of teachers connected to the school site chosen.

The CLES 2(20) was not administered to students in order to validate the teacher’s perceptions of their classroom compared to the perceptions of the students in that class. A limitation with both surveys was that they were given as a paper pencil task not as an online or bubble sheet task, so respondents were able to choose more than one response which made it difficult to calculate averages. They were also able to make other comments that added to the researcher’s understanding of their thinking.

Other limitations were the fact that the principal interviews were not piloted before the study was done. Some questions seemed redundant and no questions were asked about the African American population. The researcher allowed the interviews to flow naturally and when coding, redundancies were left out unless different language was used. Nor was the interview with the lead science teacher.

The Classroom Observation Protocol was also not piloted prior to the study, but no revisions were made between observations. The researcher wrote more narrative in the general observations section than initially planned to make sure a complete set of data
were available. However, a constructivist observation tool would have been helpful in focusing the researcher on constructivist oriented teaching and learning.

Classroom 4 was only observed two times during the data collection period, so it’s possible that the description of that class is not as complete as it could have been with more observations. The other classes were observed to the point of redundancy, but it’s likely this class was not.

As with any case study, the picture created of School D will not be generalizable to other middle schools. However, the value of this case study is iterated in Hamilton’s (2003) comments about switching the focus from large-scale reform efforts to small, grassroots reform, starting with one school and replicating what can be replicated from school to school.

Another limitation to this study would be the fact that no cases were chosen from the lowest 25th percentile on the science CSAP, predicting contrasting results to attempt at theoretical replication. This, however, could be explored in another investigation.
Chapter Four: Results

Introduction

Four site visits were made between January 12, 2012 and February 16, 2012 at which time classroom observations of four different grade levels, interviews with the principal and one teacher, and a school tour were conducted. All data, both quantitative and qualitative, were analyzed at the classroom level to create a portrait of the study school within the setting of the school, state, and district, as shown in Figure 5. Each classroom was treated as a separate case study, describing each and looking for similarities and differences in science instruction. Classrooms, however, are no longer

![Diagram](image.png)

Figure 5. Diagram showing how classrooms are nested within school, district, and state contexts.
autonomous; they operate within the context of state and district mandates and are accountable to state assessment scores.

**State Context**

**Demographics.**

854,265 students were enrolled in the state’s K-12 program during the school year 2011 – 2012. State-wide 44% of all students belong to one of several ethnic minority groups that make up the state’s population. Approximately 32% of the student population is Hispanic/Latino. African-American students make up less than 5% state-wide. An incredible 41% of the state’s students are eligible for free or reduced lunches and just over 14% of students are classified as an English Language Learner (ELL)

**Science curriculum.**

Colorado first adopted the *Colorado model content standards: Science* in June of 1995. This document described six standards; three content areas of physical, life, and earth science, one addressing inquiry, two covering the nature and technology of science. In this standards document benchmarks are clustered in grade bands; K-2, 3-5, 6-8, and 9-12. These standards were then amended in February of 2007 with very little substantive changes other than to combine standards five and six into one standard covering the nature and technology of science. In December of 2009 the Colorado Department of Education adopted *Colorado academic standards: Science* with significant changes from the earlier standards document, reducing the number of standards to the three contents of science, physical, life, and earth, and embedding inquiry and 21st century skills. This
iteration articulated grade level expectations for each grade P – 8 and reduced the number of benchmarks from 155 to 82 grade level expectations.

Prior to 2012 the CSAP in science was based on the standards and benchmarks articulated in the *Colorado model content standards: Science*. In March of 2012 the Transitional Colorado Assessment Program (TCAP) was administered and assessed, for the first time, the standards adopted in 2009 in the *Colorado academic standards: Science*. This study focused on the standards delineated in *Colorado model content standards: Science* adopted in 2007 since the district involved had not yet transitioned to the 2009 standards document.

**Resources.**

Colorado has historically been ranked near the bottom in school funding, ranking 43rd in school year 2008 – 2009 (“Great education,” 2012). In 2009 Colorado spent $2,510 less per pupil than the national average (“Colorado school,” 2012). The gap continues to grow due to huge and continuous reductions in the K-12 education budget. In the last three years funding for K-12 education at the state level has been reduced by approximately 500 million dollars. However, if one compares the costs of a fully funded state program and the total program after subtracting the Negative Factor of -12.94% in year 2011-2012 used to stabilize the budget, the decrease in school funding state-wide was more like 775 million dollars. The Colorado School Finance Project is reporting that the Negative Factor will increase to -16.1% in 2012-2013 (“Colorado school,” 2012). This is expected to cause a more than one billion dollar short-fall in K-12 education in school year 2012-2013 (“Public school finance,” 2012).
District Context

Demographics.

The study school is in the jurisdiction of one of nine districts located in the larger Denver metro area. 36,297 students were enrolled in the district’s K-12 program during the school year 2011 - 2012, with 10,695 of them enrolled in grades five through eight. Just fewer than 82% of all district students are non-White or ethnic minority while more than 82% of the students in grades five through eight are ethnic minority. Approximately 54% of the student population is Hispanic/Latino, district-wide and within the 5th through 8th grade-level. African-American students make up 18% district-wide and a little higher in grades five through eight at 18.8%. 69% of all district students are eligible for free or reduced lunches with approximately 71.5% of students in grades five through eight qualifying. 38% of district students are in the process of learning English, coming from roughly 90 different language backgrounds.

Science curriculum.

Since Colorado has no state curriculum, local school districts create their own curriculum, designing their own sequence of instruction in order to meet the state standards that were assessed on the CSAP and now on the TCAP in science. This leaves a possibility for a wide range of different science curriculum and sequences of curriculum among the 178 districts in Colorado. Appendix E shows an overview of District 4’s current pacing guide, kindergarten through grade eight. The researcher accessed the more detailed pacing guides available on the district’s web page through the division of instruction.
The elementary curriculum is a collection of Full Option Science System (FOSS) kits. Of the nineteen units to be taught through the fifth grade, fifteen units are taught with FOSS kits. The online elementary pacing guide describes the rotation of the FOSS kits, three kits per year per grade level, from one elementary school to other elementary schools in close proximity. One can connect to FOSSweb through the hyperlinks on the pacing guide to access teacher resources for each unit. Looking at a number of unit links, FOSS has clearly stated inquiry goals for each unit, but the science content objectives are vague and less concrete. For example the FOSS kit Water, taught at third grade, states the inquiry goals of asking and answering students’ questions, planning and conducting investigations, using tools to gather data, constructing reasonable explanations, and communicating about their investigations and explanations. The content objective listed is to develop students’ understanding of the properties of earth materials, including rocks, soil, water, and the gases of the atmosphere. Also included content objectives are the ideas that clouds affect weather and climate, that soils have properties and can retain water, and that water moves in the water cycle (The Regents of the University of California, 2008). Looking at the synopsis of each of the four investigations, students make general observations of the properties of water in the first set of lessons. In the second set of lessons students make a water thermometer and observe water heated, cooled, and frozen and make inferences about the densities of each. Students next explore evaporation and condensation, looking at temperature and surface area. In the last set of investigations students compare water absorption of soil and gravel, make a waterwheel
to do work, and collect local water samples and are introduced to the concept of water quality.

The pacing guides for secondary science, on the other hand, are very detailed. Referring to Appendix E one can see that the content taught and the specific units to be taught at each grade level for each quarter are listed. At sixth grade units are from the earth science standard, at seventh grade they are from life science, and at eighth grade they are from physical science with the specific topics that relate directly to the benchmarks described in the 2007 content standards document clearly listed for each quarter. When accessing the middle level pacing guides, written in 2008, from the division of instruction web page, one will notice that included for each unit of instruction are the specific benchmark, learning goals, what students should know, understand, and be able to do, inquiry lessons and labs, and resources. For example a sixth grade unit is the water cycle. The benchmark listed in the pacing guide is (4.11a) explain the processes and relationships that connect elements of the water cycle, referring to the 2007 content standards document. Students should know the water cycle, including evaporation, condensation, and precipitation. They should understand that water moves in a continuous cycle through Earth’s environment; and they should be able to draw and explain the water cycle including surface movement of water and groundwater. Inquiry lessons listed include two Project Wild/Wet activities, Water Cycle Score Card and How Much Water? Also included as an inquiry lesson is an activity to create a word wall while students research and draw diagrams of water cycling through all the places on the planet. The resources listed are pages from the textbook, *Earth’s water*, pp. 6-34.
From these middle-level science pacing guides interim assessments were created that test the science content covered during the quarter. They are administered at sixth, seventh, and eighth grade and at the end of first quarter, second quarter, and fourth quarter. Interims are twenty or so multiple-choice questions with one or two constructed response items, totaling between 25 and 35 points depending on the grade and quarter, heavily weighted toward content specific knowledge instead of science process or inquiry skills. Proficiency on each interim is approximately 70% of the possible points available. The percent of students achieving proficiency for each grade level are compared among schools, ranking them in order from most percent proficient to the school with the lowest rate of proficiency, and the data are then sent to principals. The district identifies interims as low-stakes tests that allow educators to monitor students’ progress in order to provide interventions, but at the same time, labels the science interims as end of course assessments.

**Resources.**

The district reported voluntarily decreasing its operating budget by $10 million in school year 2008-2009, not significantly impacting the instructional program. During the 2009-2010 school year, on the other hand, the district reported an effective budget increase of 5.13% from the state and a mill override was approved by voters at the November 2008 election. The downturn in the economy translated to the district experiencing a 3.6% reduction in allocations from the state due to the State Budget Stabilization Factor during school year 2010-2011, resulting in a $263 per student decrease in revenue, costing the district approximately 9 million dollars. During school
year 2011-2012, with the State Budget Stabilization Factor at nearly -13%, the budget reduction was significantly higher with a deficit of $24 million in the district operating budget (funding information from the district, withheld to maintain confidentiality).

**Professional development.**

Since Colorado has no state curriculum the responsibility for professional development in science falls to the district and the school. District professional development is structured around content area coaches that work with teachers in multiple buildings. Before budget cuts there were literacy coaches in nearly every building, math coaches for one or two buildings, and two science coaches for the entire district, one for elementary and one for secondary. After the budget cuts there were fewer literacy and math coaches, but very little had changed for science. In School D’s principal’s words,

> We don’t have a big professional development [focus] in science. Science coaches are spread very thin, much thinner than some of the other contents for sure. So when we need to improve our content understanding of our teachers we rely on our spread very thin teacher coaches.

The principal offers her opinion of the district coaching model, “I don’t feel as though it is well defined. I would like to see some different support from our teacher/district coach in terms of helping to foster that, but it just hasn’t gelled.”

The recent focus of science professional development in this district has been on science note-booking, modeled after Amaral, Garrison, and Klentschy’s work in a southern California school district (Amaral et al., 2002). “In the last few years the only thing I’ve seen is the science note-booking,” reports both the principal of School D with
the lead science teacher concurring. The principal goes on to say, “Note-buying is a great concept, but that has been the only science professional development I’ve seen.”

School Context

Demographics.

The study school is one of several K-8 schools in its district. 624 students were enrolled in the school’s K-8 program during the school year 2011 - 2012. Ethnic minority students made up 62% of the school’s population, K-8. Approximately 25% of the student population was Hispanic/Latino. African-American students made up 16.5% school-wide. 29% of the school’s students were eligible for free or reduced lunches and just over 14% of the students attending the study school were learning English. When asked about diversity and how students are scheduled into advanced courses at School D the principal called it “a beautiful blend,” adding that “We are very deliberate in how we put our classes together, so that we are not ending up with gender misbalanced classes or a racial misbalanced class” since they may only have two or three classes at each grade.

Science curriculum.

During school visits four classrooms were observed one at each of the following grade levels; third grade, fifth grade, sixth grade, and eighth grade. Seventh grade was not observed; seventh graders were in social studies classes during third quarter.

The lessons observed in each class at each grade level aligned perfectly with the district pacing guides for each grade. In third grade science instruction was from the FOSS Kit Water which is listed on the district pacing guide for third grade. The fifth grade class was working from the FOSS Kit Mixtures and Solutions, again listed on the
## Table 7

Percent of Students Performing at the Proficient or Advanced Level on the CSAP

<table>
<thead>
<tr>
<th></th>
<th>5th Grade</th>
<th></th>
<th>8th Grade</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>State</td>
<td>District 4</td>
<td>School D</td>
<td>State</td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
<td>20</td>
<td>44</td>
<td>52</td>
</tr>
<tr>
<td>White</td>
<td>55</td>
<td>37</td>
<td>61</td>
<td>65</td>
</tr>
<tr>
<td>Hispanic</td>
<td>18</td>
<td>12</td>
<td>NA</td>
<td>26</td>
</tr>
<tr>
<td>Black</td>
<td>20</td>
<td>15</td>
<td>38</td>
<td>26</td>
</tr>
<tr>
<td>Free/Reduced Lunch</td>
<td>20</td>
<td>34</td>
<td>NA</td>
<td>25</td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>23</td>
<td>39</td>
<td>46</td>
</tr>
<tr>
<td>White</td>
<td>57</td>
<td>49</td>
<td>64</td>
<td>59</td>
</tr>
<tr>
<td>Hispanic</td>
<td>19</td>
<td>12</td>
<td>NA</td>
<td>21</td>
</tr>
<tr>
<td>Black</td>
<td>22</td>
<td>18</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Free/Reduced Lunch</td>
<td>21</td>
<td>35</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>2009</td>
<td></td>
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<tr>
<td>Total</td>
<td>45</td>
<td>23</td>
<td>31</td>
<td>49</td>
</tr>
<tr>
<td>White</td>
<td>58</td>
<td>45</td>
<td>38</td>
<td>61</td>
</tr>
<tr>
<td>Hispanic</td>
<td>21</td>
<td>15</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Black</td>
<td>24</td>
<td>18</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>Free/Reduced Lunch</td>
<td>23</td>
<td>40</td>
<td>21</td>
<td>26</td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>47</td>
<td>23</td>
<td>63</td>
<td>49</td>
</tr>
<tr>
<td>White</td>
<td>61</td>
<td>44</td>
<td>71</td>
<td>61</td>
</tr>
<tr>
<td>Hispanic</td>
<td>23</td>
<td>16</td>
<td>60</td>
<td>25</td>
</tr>
<tr>
<td>Black</td>
<td>25</td>
<td>19</td>
<td>41</td>
<td>26</td>
</tr>
<tr>
<td>Free/Reduced Lunch</td>
<td>26</td>
<td>40</td>
<td>54</td>
<td>27</td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>47</td>
<td>20</td>
<td>32</td>
<td>49</td>
</tr>
<tr>
<td>White</td>
<td>61</td>
<td>42</td>
<td>35</td>
<td>62</td>
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<tr>
<td>Hispanic</td>
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<td>13</td>
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<td>28</td>
</tr>
<tr>
<td>Black</td>
<td>23</td>
<td>15</td>
<td>19</td>
<td>26</td>
</tr>
<tr>
<td>Free/Reduced Lunch</td>
<td>26</td>
<td>39</td>
<td>31</td>
<td>28</td>
</tr>
</tbody>
</table>

Note: Data for this table was retrieved from the Colorado Department of Education, Unit of Student Assessment Website, January 22, 2012
district pacing guide for fifth grade. The district pacing guide is more specific for the sixth grade and students were learning about Earth’s waters and on the last observation of this class students began their study of weather, exactly what is listed for third quarter on the sixth grade pacing guide. During the span of classroom visits to the eighth grade class, instruction in conservation of energy, energy transformations, and light were observed, listed on the third quarter pacing guide for eighth grade.

Table 7 provides an historical look at the percent of 5th and 8th graders from School D who were proficient on the CSAP between 2007 to 2011. It’s easily seen that science CSAP scores for eighth grade students in 2009 were an anomaly for all groups when compared to the CSAP scores for the different groups at the fifth and eighth grade level during school years 2007 through 2011.

Resources.

Since a huge percent of a school’s budget is personnel, a decision made at the district level is the number of Teacher Equivalencies (TE) each school receives based on the district budget and the number of students projected to enroll in the school. The principal then needs to decide how to allocate those TE to best staff the school to meet students’ instructional needs. The principal, referring to state and district budget cuts stated,

I could dedicate more TE toward science instruction and each year as the TE gets chipped away we needed to reallocate human resources, my teachers, frankly. Because the instructional minutes are not the same as literacy and math, [science is] an area I had to consider trimming.

TE at this school directly translated into minutes of science instructional time. At grades five through eight the schedule was organized into blocks of time of 105 minutes each.
Before the state and district budget cuts students received 105 minutes of science instruction every day, the same as literacy and math. After the budget cuts and the reduction in TE, students alternated science with social studies; fifth and eighth grade alternated every other quarter, first quarter and third quarter, while sixth grade alternated every other day. At third grade students received science/social studies instruction 30 minutes each day and alternated science units with social studies units.

Each school within the district is given a small amount of dollars for their general funding of programs. At School D they received roughly $70,000 to support all programs, including science. The principal explained her philosophy for allocation, "I function more from the zero-based budget, so I allocate as needed instead of giving funds to departments.” If consumables are then needed for the science program, the teacher makes a request and the items are purchased. In the principal’s own words:

Ours is different, you tell me what you need and we’ll find the money for it. If my general budget couldn’t cover something and I knew that our kids need that to learn and our teachers need that to teach, I would find the money for it somewhere else.

At the elementary level the school used the FOSS kits, in alignment and on the schedule of the elementary pacing guide, which rotated throughout the district; so the district maintained the responsibility for replacing the consumable materials before it was delivered to School D.

When the school was opened they were able to fully supply the science program from the new school budget. The school was built with two fully outfitted, dedicated science classrooms, the seventh/eighth teacher is in one and the other is available when needed for other grades. The other science classrooms that were observed all had sinks
built into the room, even the third grade classroom. From this budget they bought science kits; more than thirteen FOSS kits, thirteen Science and Technology for Children (STC) kits, and three other kits were observed in the science supply room between the two science classrooms. All four teachers surveyed report having the following fully available; balances and spring scales, glassware such as beakers, graduated cylinders, etc., thermometers, metric rulers, water for experiments, and rocks, sand, and minerals. Two of the four reported having microscopes, stop watches, and probe ware (e.g. motion detectors, temperature, and salinity) partially available instead of fully available and one teacher did not know about the availability of chemical reagents.

**Professional development.**

Data about professional development was gathered as part of the RAND survey. Teachers indicated the amount of time spent in different professional development activities during the past 12 months. The activities related to the study of content, pedagogy and curriculum. The survey also asked about opportunities teachers had to work with colleagues, either in teams or with peer coaches. Table 8 shows each possible professional development activity asked about on the RAND survey and the responses teachers chose for the time spent in each of those activities.

When looked at together teachers were not very likely to spend more than eight hours in the past year on any of the science professional development activities. The exceptions were two: activities pertaining to teaching diverse populations of students, two teachers responded with 4-8 hours and two teachers responded with 9-16 hours, and having the opportunity to collaborate with other teachers, two teachers responded with
Table 8
Frequency Table Showing the Amount of Time Spent in Different Professional Development Activities Within the Past 12 Months

<table>
<thead>
<tr>
<th>Activity</th>
<th>None</th>
<th>Less than 4 hours</th>
<th>4 – 8 hours</th>
<th>9 – 16 hours</th>
<th>More than 16 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-depth study of science content</td>
<td>//</td>
<td>//</td>
<td>/</td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>Methods of teaching science</td>
<td>//</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>Use of particular science curricula or curriculum materials</td>
<td>/</td>
<td>//</td>
<td>/</td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>Students’ scientific thinking</td>
<td>/</td>
<td>//</td>
<td>/</td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>Science standards or framework (NSES, NSTA, AAAS, state and / or district)</td>
<td>/</td>
<td>//</td>
<td>/</td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>Science assessment / testing</td>
<td>//</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>Use of educational technology for science instruction</td>
<td>//</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>Strategies for teaching diverse student populations</td>
<td>//</td>
<td>//</td>
<td></td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>Opportunities for collaborating with peers, team teaching, or peer coaching</td>
<td>//</td>
<td>//</td>
<td></td>
<td>/</td>
<td></td>
</tr>
</tbody>
</table>

Note. Each back slash represents one teacher from School D that completed the RAND survey.

4-8 hours and two teachers responded with more than 16 hours, neither one of these activities were framed specific to science. The exceptions to this are the three single responses at more than 16 hours. The same teacher indicated she spent more than 16 hours during the past year involved in professional development pertaining to methods of teaching science, students’ scientific thinking, and use of educational technology for
science instruction. No follow up was done to find out the context for this teacher’s responses given that they were outliers.

Three of the four teachers responded that they had received either none or less than four hours of professional development in six of the seven science specific activities listed. Methods of teaching science, science assessment, and use of educational technology for science instruction had more teachers responding that they had received no professional development in these areas. Three teachers responded that they received either none or less than four hours in the areas of use of particular science curricula or curriculum materials, students’ scientific thinking, and science standards or frameworks, including state and/or district. For the activity in-depth study of science content two teachers responded that they had less than four hours of professional development and two teachers responded that they had between four and eight hours.

During the principal interview several questions were asked about professional development and the topic came up again during the follow up interview. The principal reported that, “we have elementary teachers teaching science without a strong content knowledge of science.” Teachers are also saying that they don’t feel as comfortable teaching the science content and identified it as one of their root causes in the school’s Unified Improvement Plan (UIP). The principal noted that the 6th grade and the 7th/8th grade teachers are both highly qualified to teach science, “. . . so they are definitely much stronger.” She does admit, “I can’t say that we have done much to be able to improve [teachers’ science content knowledge].” When speaking of the lead science teacher in the building, the principal stated, “I know she serves as a support for elementary teachers
who might not feel as comfortable in the content.” However, the lead science teacher stated that as the science resource teacher, “. . . no one has asked for anything. Last year someone asked me to go buy them vinegar and I had to go pick up critters [animals] at another school.”

Elementary science is based entirely on FOSS kits supplied by the district. All four teachers reported they’ve received less than eight hours of professional development in the use of particular science curricula or curriculum materials. The principal stated in reference to FOSS kits,

I can monitor the fidelity of how teachers are implementing the FOSS kits. I can ensure that students are reaching learning target goals, but I can’t guarantee [teachers’] content knowledge, their passion. How can we make sure that students are building a fundamental understanding of science versus a really fun activity?

At one point a district science coach came to work with a grade level on their understanding of a FOSS kit, instead of helping them with their questions or modeling how to use the kit, she lectured the group on the science concept. In summarizing the partnership currently with the district, the principal said, “I don’t feel like we’ve got our stride with the district coach with whom we are working with to really get that content knowledge through professional development.”

School D has fully embraced science note-booking. The principal described the working relationship with a previous science coach and science note-booking. “[She] was very involved in what we were doing in our school, worked with teachers not only in science but also the other content areas and really took the note-booking approach and plugged it into other content areas.” She added, “You would see it in places you wouldn’t
expect it, PE for instance and that idea of note-booking; and it’s not going to look the same, but you would definitely see it across content and grade levels."

It was observed at each grade during every observation in all four classrooms. In classroom 1, students constructed their data table following the teacher’s example for the energy transformations activity and after debriefing wrote their conclusion

**Conclusion**
In today’s lab I learned . . .

As students began the roller coaster activity the teacher wrote:

**Background Knowledge**
2-3 sentences

The teacher in classroom 2 had students write every investigation in their science notebooks. In classroom 3 students were directed to write from the teacher’s model:

**Ocean water**
**BK**
T – “What do you know so far about ocean waters?”
“what makes you think that?”

**Notes**
T – “topic and details connected to purpose”
T – “what features will help us determine topics?”

And on another day she was observed writing in her science notebook:

Purpose: Deepen my understanding of the physical characteristics of ocean water
Research question: What is the relationship between ocean layers, density, and salinity?

Classroom 4’s teacher was observed saying, “. . . journals open to your science question” and “Take notes of your journey.”
Teachers responded on the survey that they had between four and 16 hours devoted to professional development around strategies of teaching diverse students. The principal expressed a strong emphasis on,

. . . first of all understanding our needs when we talk about diversity; we really unpack it from students of color, to students of poverty, to gender, to all kinds of things, learning disability, all kinds of things. So, we really try to get smarter about what different needs are and then we can talk about how do we address that.

When asked by the researcher, “Is that a recurring topic during staff development?” She answered,

It is and we really look at, we monitor our data carefully because what we were noticing, it was three years ago, this incredible skew in the number of African American males that were referred out of class and so we really paid attention to that and have been monitoring that and addressing that head on.

Two classroom observations on the same day included a small portion of class time devoted to a discussion of a ‘No Place for Hate’ article and it was mentioned that it was ‘No Place for Hate’ week. The principal describes this initiative as one “that’s really to continue to develop that cultural sensitivity and cultural awareness and what you’ll hear in the literature is cultural responsiveness.”

The last activity asked about on the RAND survey was opportunities to collaborate with peers, two teachers responded with having 4-8 hours and two teachers responded with having more than 16 hours. When asked about time for science teachers to work together, the principal indicated that, “There are spotty opportunities for this. Quite frankly we are working on our major improvement strategies [not science].” She goes on to describe that teachers can collaborate about science within their own planning time, one hour at the end of the day four times a week, or during grade level planning
saying, “I think the opportunity is there. I don’t feel as though it is well defined.” When asked when science teachers could collaborate with language acquisition teachers, she responded that that collaboration would also happen during grade level planning.

The teachers really plan together … planning is coherent and they always bring in that ELD, what kids are learning during that block and how kids are applying it to every content and so I’m not sure if you would see it specific to science, but you would see it show up in their planning, whether they are planning for science or planning for reading, writing, or math.

Classroom Cases

Four classrooms in the study school were selected because they were teaching science during third quarter. As mentioned above science instruction was alternated with social studies instruction. Four school visits were made between January 12, 2012 and February 16, 2012. At the time classroom observations were made, the two surveys (see Appendix C) were explained to teachers, the revised RAND Teacher Survey and the CLES 2(20), and informed consent forms were completed for both observations and surveys (see Appendix B).

Classroom 1.

Classroom 1 was an eighth grade science class with approximately 20 to 23 students, depending on the day it was observed. Of the twenty students on one observation day, thirteen students were boys and thirteen of the twenty were students of color, a very diverse class. The teacher reported that approximately 22% of her students were ELL students. Students were grouped a tables of four students, mixing boys and girls and ethnicity with a variety of science ability. Students were very clear on the start of class expectations as they got started on their own. The teacher was very organized and
had an easy rapport with her students. She is White (not of Hispanic origin), has a master’s degree and majored and minored in Biology and Pre-Med as an undergraduate. Including school year 2011-2012, she had taught a total of seven years, seven years as a science teachers and five years at grades seven and eight. She has served as the school’s science lead teacher for the past three years. She reports feeling very confident in the knowledge of the science she needs to teach.

The beginning of the RAND survey asks general questions about how teachers think about teaching their own curriculum. When asked on question 4 of the RAND survey about how much emphasis, using a 4-point Likert scale ranging from no emphasis to great emphasis was placed on a variety of skills and activities when teaching the science content, the teacher responded with an overall average of 2.7 out of 4. A difference was noted between the items that were more inquiry-oriented, averaging 3.0, and the items that were less inquiry-oriented, averaging 2.1, indicating that she puts moderate emphasis on more inquiry-oriented options and slight emphasis on less inquiry-oriented options, as shown in Table 9 and Figure 6. None of the options were given great emphasis.

When asked how often she employed a selection of teaching strategies, she indicated that she would use all of them once or twice a week, inquiry-oriented and other strategies. Question 6 asked how often students would engage in different activities, the average of all the choices was 3.4 on a 5-point Likert scale ranging from never to almost every day. For the inquiry-oriented choices, like engage in hands-on science and share
ideas and problem-solve with peers, the average response was 4; all but one activity was rated a 5, almost every day, except the activity of working on extended science investigations which the teacher rated a 1, never. Students were less likely to engage in activities that were not inquiry-oriented with an average response of 2.75 of 5, as shown on Table 9. Generally it seems that the teacher in classroom 1 leaned more toward inquiry-oriented instructional strategies than those that are not, shown in Figure 6.

The rest of the survey asks teachers to respond to information about two mythical classes and put themselves in the position of the teacher in each class. Response choices are on a 4-point Likert scale, ranging from very unlikely to very likely. The beginning of each scenario asks the teacher how likely they are to use different strategies as an initial activity to the unit of study. The average response was 3.2 of 4, indicating somewhat
likely and leaning toward very likely to engage in the variety of activities to introduce the unit. She indicated that she would be very likely to introduce each unit using inquiry-oriented activities with an average of 4 of 4. The other activities received an average of 2.5, somewhere between somewhat unlikely and somewhat likely.

The next set of questions asks how the teacher will respond to students who have made mistakes or have misconceptions. The teacher in classroom 1 responded with a total average of 2.75 with more inquiry-oriented options receiving an average of 2.7 and other options averaging 2.8, putting the responses closer to somewhat likely than somewhat unlikely. However, she consistently chose a 1, very unlikely, to responses that might have embarrassed or belittled the student involved.
The third set of questions asks teachers to respond to different ways of handling student disagreements about the phenomena under study. Classroom 1’s teacher rated the choices that were more inquiry-oriented higher, an average of 3.7, than the other choices, an average of 2.75. The total average for this set of questions was 3.0, somewhat likely, shown in Table 9. She indicated that she would be more likely to use inquiry-oriented strategies over other less inquiry-oriented strategies.

The last set of questions asks for how much emphasis the teacher would place on different learning objectives specific to the scenarios, some more inquiry-oriented than others. The teacher’s total average was 3.2 with inquiry-oriented responses averaging 3.6 and the other options averaging 3, showing a propensity toward a greater emphasis on inquiry-oriented objectives and a moderate emphasis on all the options reform or otherwise. Looking at Figure 6, it is clear that the teacher in classroom 1 prefers inquiry-oriented strategies overall and particularly for student activities within her own classroom and for introductory activities in the hypothetical classroom.

To compare teachers’ theoretical attitudes toward reform-oriented, inquiry based science teaching, classrooms were observed using the Essential Features of Classroom Inquiry (see Appendix G; National Research Council, 2000, p. 29) to focus the researcher on inquiry practices. Narrative descriptions were recorded during observations to provide a voice. Figure 7 shows the mean of each component of the Essential Features for the three observations done in Classroom 1. The highest rating possible for each component was a 4, representing the most learner self-direction and the least amount of direction.
from the teacher or the material. A zero was used for not observed. So a classroom that was most inquiry-based would have an average of 4 for each component.

There are five components to the Essential Features observation protocol. The first concerns the learner posing their own testable question, more learner self-direction, on a continuum to the learner engaging in a question provided for them either by the teacher or the materials, less learner self-direction. As shown in Figure 7 over the course of three observations in Classroom 1, the mean of students posing their own questions was 1.67. As an introductory activity for waves students were given water and rope and told to make waves. In another exploration activity about potential and kinetic energy, students were asked to design a roller coaster from pipe insulation material that would get a marble from start to finish without losing the marble off the track.

At the other end of the spectrum, the teacher in classroom 1 primarily used lab packets to organize students’ investigations. The student packet for the pendulum lab had the question written for each of three problems; How does the starting height of the swing affect the number of swings of a pendulum? How does the mass of the bob affect the number of swings of a pendulum? and How does the length of the string affect the number of swings of a pendulum?

The next component involves the learner is making decisions about the evidence or data they need in order to answer their own question. The mean in classroom 1 was 3 of 4. The teacher of classroom 1 consistently either had students copy data tables from the teacher’s science note-book projected on the Promethean board at the front of the
room, energy transfer activity, or had blank data tables for students to complete as part of their lab packets, conduction, pendulum, and waves labs.

Next the learner formulates explanations from the evidence. Students were consistently given possible ways to use evidence to formulate an explanation, a mean rating of 2. At the end of the energy transformation activity the teacher led the students in a debriefing session about the 16 stations they had been working at exploring energy transformations. The teacher led students in completing their data tables and asking students to explain why each activity was an example of energy transformations. When

![Figure 7. Mean of each Component of the Essential Features of Classroom Inquiry for Classroom 1](image-url)
finishing the pendulum lab the teacher of classroom 1 moved from group to group
guiding students to compare the string length of the pendulum with the evidence in their
data tables and graph to formulate a conclusion. The packet for this lab activity included
directions for creating a claims and evidence chart in students’ science notebooks, the
teacher told students not to do this part due to time concerns. The packet also included a
statement to focus students on a conclusion: In a statement tell if your hypothesis was
supported or not, and what the real answer to the problem is. The conduction and waves
lab packets had discussion questions at the end.

It’s important for students to connect their explanations to scientific knowledge.
In classroom 1, students were generally given possible connections, with a mean rating of
1.33 shown in Figure 6. This component was not observed during one observation and it
was scored a zero on that day. At the end of the pendulum lab the teacher was leading a
class discussion on why a longer string gives the pendulum a longer period. In the waves
activity students were directed to the pages in the science textbook to find pictures,
labels, and answers to questions for longitudinal and transverse waves.

The last component of the Essential Features of Classroom Inquiry indicates how
independently the student forms reasonable and logical argument to communicate their
explanations. The students in classroom 1 were consistently given the steps and
procedures for communication, a mean rating of 1, usually a set of questions at the end of
each lab activity. At the end of the energy transformation activity and after a class
discussion of the energy transformations students observed that day, the teacher led
students in writing: Conclusion – In today’s lab I learned . . . in their science notebooks.
On the pendulum lab there were conclusion questions for students to complete, ranging from questions asking students to recall what they learned in each section of the lab to asking students to extrapolate from the graph of string length v. number of swings. On the conduction lab students were asked to define conduction and conservation of energy and included short answer and discussion questions for students to complete.

The second survey teachers completed was the CLES 2(20), a revised Constructivist Learning Environment Survey (CLES) reducing the number of questions overall but retaining the validity of the original (Johnson & McClure, 2004). The CLES 2(20) uses a 5-point Likert scale, scaled from almost never to almost always, so means shown on Table 10 are compared to 5, environments that are the most constructivist or student-centered. A couple of the teacher’s responses stood out from the rest. She responded that students seldom learn that science is influenced by people’s cultural values and opinions. She also indicated that students almost always talk with other students about how to solve problems. The preponderance of responses to each question were 4 or often. Looking at the data in Table 10, the teacher in classroom 1 reported that her class is more often than not student-centered or constructivist in nature.

Table 10

| Personal Relevance/ Learning about the World | 4 |
| Uncertainty/ Learning about Science          | 3.25 |
| Critical Voice/ Learning to Speak Out       | 4 |
| Shared Control/ Learning to Learn           | 3.75 |
| Student Negotiation/ Learning to Communicate| 3.75 |
| **Total**                                   | **3.75** |
The researcher attempted to discern the constructivist scales in action in classroom 1 from the classroom narrative in order to associate the theoretical responses from the teacher to what might be present in the classroom on a daily basis. Activities provided for students by the teacher to introduce and reinforce learning were highly engaging. Personal relevance may have been exemplified when students were moving through stations with different everyday objects, flashlights, candy, and windup toys that demonstrated energy transfer. In another activity students were challenged to make waves in a container of water. No observations were made that could be classified as belonging to uncertainty.

Critical voice is a scale that measures how safe students feel in questioning and asking for help. It was evident watching the teacher interact with her students that they felt safe to ask for help or clarification when confused and to express concern about anything that got in the way of their learning. On the RAND survey this teacher responded consistently with very unlikely to any choices that might have embarrassed or belittled a student. For the scale shared control, it was observed that the teacher was flexible in her timing of classroom activities, allowing more time if students hadn’t completed an activity.

Student negotiation or learning to communicate was observed during every classroom observation. Students were working together more than they were working independently. At the beginning of class students were given review questions to work together on as class starters. Students worked together on investigations and negotiated their understandings. Students helped each other finish conclusion questions at the end of
lab packets. Students had to negotiate with others when designing their roller coasters and creating waves.

**Classroom 2.**

Classroom 2 was a fifth grade class with approximately 26 students. The day these counts were made, twelve students were boys and thirteen were girls for a total of 25, ten of which were Anglo and 13% of the students were reported to be ELL students. Students were grouped at tables with four to six students with boys and girls evenly mixed. There seemed to be some groups that were more capable of working independently then other groups. The teacher of classroom 2 reported that she is White (not of Hispanic origin), has multiple master’s degrees, but did not major or minor in a science field during her undergraduate studies. Of the four classrooms studied, classroom 2’s teacher had the most years of teaching experience at a total of 17 years. She reports having taught science for three years and fifth grade for six years. She has not served as a lead teacher in science, but reports being very confident in her knowledge of the science she needs to teach.

When asked about how much emphasis was placed on learning a variety of skills and activities when teaching her own content, the teacher of classroom 2 responded with an overall average of 3.25. There was no difference reported on the averages between the emphasis placed on inquiry-oriented skills and activities and those that would be considered less inquiry-oriented, both averaging 3.25, indicating a more than moderate emphasis on all activities (see Table 11). However, the teacher responded with slight emphasis to learning specific information about the content area, learning about the
Table 11
Classroom 2 Teacher Mean Response Scores on the RAND Survey of Instructional Choices

<table>
<thead>
<tr>
<th>RAND Survey Questions</th>
<th>Total</th>
<th>Inquiry-oriented</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Teaching Strategies(^a)</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>6. Student Activities(^a)</td>
<td>4</td>
<td>4.75</td>
<td>3.25</td>
</tr>
<tr>
<td>8/12 Introductory Activities</td>
<td>2.9</td>
<td>3.2</td>
<td>2.7</td>
</tr>
<tr>
<td>9/13 Response to Student Error</td>
<td>2.3</td>
<td>3.5</td>
<td>1.9</td>
</tr>
<tr>
<td>10/14 Differing Explanations</td>
<td>2.9</td>
<td>3.7</td>
<td>2.6</td>
</tr>
<tr>
<td>11/15 Emphasis on Learning Objectives</td>
<td>3.27</td>
<td>3.2</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Note. \(^a\)These means are on a 5-point Likert scale. The rest of the table is based on a 4-point Likert scale.

collection of science to everyday life, and carrying out a planned experiment. Half of the eight skills and activities were rated with a 4, or great emphasis. When asked how often she employed a selection of teaching strategies, she indicated that she would use half of the strategies almost every day, a Likert scale of 5, and the other half once or twice a month, a scale rating of 3, averaging 4 on both inquiry-oriented and other.

Question 6 asked how often students would engage in different activities, the average of all the choices was 4 on a 5-point Likert scale ranging from never to almost every day. For the inquiry-oriented choices, like engage in hands-on science, work on extended science investigations or projects, and share ideas and problem-solve with peers, the average response was 4.75, indicating nearly every day. Students were apt to engage in activities that were not inquiry-oriented much less frequently with an average
response of 3.25 of 5, as shown on Table 11 and Figure 8. When asked about the frequency of short-answer tests, this teacher indicated that students would likely do this a few times a year. Generally it seems that the teacher in classroom 2 leaned more toward inquiry-oriented instructional strategies than those that are not.

The rest of the survey asks teachers to respond to information about two hypothetical classes and put themselves in the position of the teacher in each class. Response choices are on a 4-point Likert scale, ranging from very unlikely to very likely. The beginning of each scenario asks the teacher how likely they are to use different strategies as an initial activity to the unit of study. The classroom 2 teacher’s average response was 2.9 of 4, indicating somewhat likely to engage in the variety of activities offered that introduce the unit. She indicated that she would be somewhat likely to
introduce each unit using inquiry-oriented activities with an average of 3.2 of 4. The other activities received an average of 2.7, leaning more toward somewhat likely. She indicated that she would be very unlikely to have students read a short segment from a textbook describing a spring’s motion and the factors which affect its bounce and very likely to give students different springs and masses to experiment with. When asked about the initial activities for the heredity unit, if she was very likely to use an introductory activity, she rated it a 4. On activities that she rated less than 4 she was not as certain in her rating, circling two options either very unlikely and somewhat unlikely or somewhat unlikely and somewhat likely.

The next set of questions asks how the teacher would respond to students who have made mistakes or have misconceptions. The teacher in classroom 2 responded with a total average of 2.3 with more inquiry-oriented options receiving an average of 3.5 and other options averaging 1.9, indicating she would be somewhat unlikely to respond to students with less inquiry-oriented options and more likely to respond with inquiry-oriented options. Her responses indicated that she would be very unlikely to make choices that directly give the answer to students and more likely to lead students toward their own correct answer, shown in Figure 8. Again, on questions related to the heredity unit, unless she was sure that she was very unlikely to choose an option, she chose more than one, circling 1 and 2, circling 2 and 3, and circling 3 and 4.

The third set of questions asks teachers to respond to different ways of handling students’ differing explanations about the phenomena under study. Classroom 2’s teacher rated the choices that were more inquiry-oriented higher, an average of 3.7, leaning closer
to very likely to use inquiry-oriented options than the other choices, an average of 2.6. The total average for this set of questions was 2.9, somewhat likely, shown in Table 10 and Figure 8. She indicated that she would be very likely to choose to have the two groups show how they used Punnett squares to reach their conclusions in the heredity unit by both circling the 4, very likely, and drawing a star next to it. As with the previous set of questions, she would be unlikely to respond in such a way as to solve the disagreement for students.

The last set of questions asks for how much emphasis the teacher would place on different learning objectives specific to the scenarios, some more inquiry-oriented than others. The teacher’s total average was 3.27 with inquiry-oriented responses averaging 3.2 and the other options averaging 3.3, showing very little difference between choosing more inquiry-oriented options over less inquiry-oriented ones. She added the comment, “lower level” to her survey next to the option for students will be able to define the terms gene, offspring, pure, and hybrid, but she indicated she would give it moderate emphasis during the unit on heredity. Figure 8 shows that teacher 2 is much more likely to use inquiry-based instructional strategies in her current classroom and when responding to student error and differing explanations for the hypothetical classroom.

Classroom 2 was also observed using the Essential Features of Classroom Inquiry. There are five components to the Essential Features observation protocol: asking questions, determining the evidence needed, formulating explanations, connecting to scientific knowledge, and communicating findings appropriately. The highest rating possible for each component was a 4, representing the most learner self-direction and the
least amount of direction from the teacher or the material. A zero was used for not observed. So a classroom that was most inquiry-based would have an average of 4 for each component. Figure 9 shows the mean of each component of the Essential Features for the three observations done in Classroom 2.

![Bar chart showing mean of each component of Essential Features of Classroom Inquiry for Classroom 2]

The first of the five components concerns the learner posing their own testable question, more learner self-direction, on a continuum to the learner engaging in a question provided for them either by the teacher or the materials, less learner self-direction. Over the course of three observations in Classroom 2, the mean of students posing their own questions was 1.67. Primarily the questions were posed by the FOSS kit
that students were working through, Mixtures and Solutions. During the first observation students were working on their second investigation. The day before students had developed a question based on the first lab they had done. Students were revising their questions as they were conducting the investigation, asking, what happens after evaporation? During the second observation students were using the FOSS procedures to write a question for their investigation. One group while working on investigation number 4 came up with their own question after a student read the procedures aloud to the group. They weren’t quite sure if that was correct, so they also wrote the teacher’s question posted at the equipment table. On the last observation day students were given the question, do 3 liquids have different amounts of NaCl?

The second component of the inquiry protocol is how much control the student has over determining what evidence is important in answering their question. In classroom 2 the mean rating was a 3 of 4. FOSS kits are very investigation oriented so frequently a data collection organizer is given to students. Apparently on investigation 1 students were making their own choices about how to organize their data because on the first observation day the teacher was leading a discussion with students about what information they needed. The class decided on a T chart showing Before / After. The teacher challenged students to think about, does this change what you know? For the next investigations students were directed in what to data to collect by the procedures in the FOSS investigations.

The next component pertains to students formulating their explanation from their evidence. This was only observed once during the three observations when the teacher
lead a class discussion asking students to think about why the water was rising, this came after students had added salt to a container of water. The overall mean rating was then a 1. Students also need to connect what they have observed in investigations to related scientific knowledge. This component was given a mean of 0 since it was not observed during any of the three observations. One student, however, was observed during a later investigation making a connection to something he learned in investigation 1 done in the previous week. Students were observed reading a selection in the FOSS textbook, in which the content related to the periodic table not the learning target which was: We are looking at saturation of a solution to explain the properties of solids.

The last component of the Essential Features of Classroom Inquiry is how much control the learner has over how they communicate and justify their explanations. This area was rated a 0.67. On two of the three observations students were working on writing a complete lab write up. Posted at the front of the class both on a flipchart and the whiteboard was the following: 1. ?; 2. Hypothesis/BK; 3. Materials; 4. Procedures; 5. Data; 6. Conclusion. The teacher was moving from group to group checking, grading, and providing feedback to students on their lab write ups. The instruction in each section of the lab write up was not observed.

Table 1 shows teacher 2’s response averages on the CLES 2(20). Means on the CLES 2(20) are compared to 5, environments that are the most constructivist or student-centered. This teacher’s responses indicate that she is very constructivist in her orientation toward teaching and learning. Similar to the teacher in classroom 1, her lowest average was on the scale for uncertainty, providing opportunities for students to
Table 12
Classroom 2 Teacher Mean Response Scores on the CLES 2(20)

<table>
<thead>
<tr>
<th>Construct</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Relevance/ Learning about the World</td>
<td>4</td>
</tr>
<tr>
<td>Uncertainty/ Learning about Science</td>
<td>3.25</td>
</tr>
<tr>
<td>Critical Voice/ Learning to Speak Out</td>
<td>5</td>
</tr>
<tr>
<td>Shared Control/ Learning to Learn</td>
<td>4</td>
</tr>
<tr>
<td>Student Negotiation/ Learning to Communicate</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4.25</strong></td>
</tr>
</tbody>
</table>

experience the changing nature of science. She responded with a 2, seldom, for the statement that said that students learn that science is influenced by people’s cultural values and opinions.

The researcher attempted to identify the constructivist scales in action in classroom 2 from the classroom narrative in order to associate the theoretical responses from the teacher to what might be present in the classroom on a daily basis. No observations were made that could be classified as belonging to personal relevance, learning about the world, uncertainty, learning about science, or critical voice, learning to speak out.

Observations were, however, made in the area of shared control. At the end of most every class period, the teacher called students to the rug at the front of the room for a class meeting. This appeared to be a consistent part of the schedule. Here she asked how class went for them; specifically during one observation she elicited feedback on the format of the class where students were working independently at various stages through the progression of investigations on Mixtures and Solutions by asking, “Today, what did you learn?” During another observation the teacher was observed saying, “come to the
Students responded thusly; “I learned how to make a graph.” “I learned that even if absent, I have to do the work.” “I learned that if I don’t understand something, I need to get help.” On the RAND survey her responses indicated that she would be very unlikely to make choices that directly give the answer to students and more likely to lead students toward their own correct answer. That very much appeared to be the norm in classroom 2. On two occasions the teacher was observed spending the majority of the class period meeting with groups, discussing and grading their lab write ups and discussing proficiency on those lab write ups, informing students what they can do to become advanced, “to be advanced I want you to have a graph in every lab.”

Student negotiation or learning to communicate was observed during every classroom observation. Students were working together conducting investigations as much as they were working independently on writing their lab write ups. During one observation students in one group were working on writing up an investigation on separating salt from water. A student was observed reading their scientific question to their group and supporting their choice as to why they wrote that question. In another group a student was observed asking a question of their group members. During the class observation the next week, students in one group in particular were observed working together to create their testable question from the FOSS procedures given to them and then continuing independently working on completing the new investigation. During the last classroom observation, a number of students were gathered on the floor next to the
net book cart and working together, some showing others, how to use ‘Create a Graph’ to
graph the data collected from their investigations.

**Classroom 3.**

Classroom 3 is a sixth grade science class with between 24 and 28 students; this
teacher teaches two sections of science on alternating days. On the observation day that
counts were made, of the 28 students thirteen were boys and fifteen were girls, with 21
students of color. The teacher of classroom 3 did not indicate how many of her students
were English Language Learner (ELL) students. Students were seated at tables with four
to five other students with seats assigned using a randomizing seating chart. This created
a mix of ethnicity, gender, and science ability at each table grouping. She responded on
the survey that she is White (not of Hispanic origin) and has her bachelor’s degree,
majoring in science. She has taught a total of ten years, five at the sixth grade and five
teaching science. She has not served as a lead teacher, but reports feeling moderately
confident in teaching the content she is asked to teach.

The beginning of the RAND survey asks general questions about how teachers
think about teaching their own curriculum. When asked on question 4 of the RAND
survey about how much emphasis, using a 4-point Likert scale ranging from no emphasis
to great emphasis was placed on a variety of skills and activities when teaching the
science content, the teacher responded with an overall average of 3.3 out of 4. A small
difference was noted between the items that were more reform-oriented, averaging 3.0,
and the items that were less reform-oriented, averaging 3.5 as shown in Table 13 and
Figure 10. None of the options were given no emphasis or slight emphasis. All options were either moderate or great emphasis.

When asked how often she employed a selection of teaching strategies, she indicated that she would use all of them either once or twice a week or almost every day. The total mean of all choices was a 4.5, with more inquiry-oriented strategies averaging 4.5 as was the mean of other, less inquiry-oriented strategies, indicating she would be as likely to use lecture as to encourage students to consider alternative explanations. When asked how often students would be engaged in different learning activities, the average of

Table 13

Classroom 3 Teacher Mean Response Scores on the RAND Survey of Instructional Choices

<table>
<thead>
<tr>
<th>RAND Survey Questions</th>
<th>Total</th>
<th>Inquiry-oriented</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Emphasis on Learning Objectives</td>
<td>3.3</td>
<td>3</td>
<td>3.5</td>
</tr>
<tr>
<td>5. Teaching Strategies&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>6. Student Activities&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.4</td>
<td>3.25</td>
<td>3.5</td>
</tr>
<tr>
<td>8/12 Introductory Activities</td>
<td>2.6</td>
<td>3</td>
<td>2.4</td>
</tr>
<tr>
<td>9/13 Response to Student Error</td>
<td>2.3</td>
<td>3</td>
<td>2.1</td>
</tr>
<tr>
<td>10/14 Differing Explanations</td>
<td>2.5</td>
<td>3.3</td>
<td>2.1</td>
</tr>
<tr>
<td>11/15 Emphasis on Learning Objectives</td>
<td>3.1</td>
<td>2.6</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Note. <sup>a</sup>These means are on a 5-point Likert scale. The rest of the table is based on a 4-point Likert scale.

all the choices was 3.4 on a 5-point Likert scale ranging from never to almost every day. Activities rated as inquiry-oriented had a mean of 3.25 while those that were other than inquiry-oriented averaged 3.5, showing a slight leaning toward student activities that are less inquiry-oriented. As with classroom 1 and classroom 4 teachers, the teacher of
classroom 3 rated the choice of students working on extended science investigations the lowest at 2, a few times a year. She indicated that she would not use any of the learning activities almost every day.

The rest of the survey asks teachers to respond to information about two mythical classes and put themselves in the position of the teacher in each class. Response choices are on a 4-point Likert scale, ranging from very unlikely to very likely. The beginning of each scenario asks the teacher how likely they are to use different strategies as an initial activity to the unit of study. The average response for classroom 3 teacher was 2.6 of 4. She indicated that she would be somewhat likely to introduce each unit using inquiry-oriented activities with an average of 3 of 4. The other activities received an average of 2.4, somewhere between somewhat unlikely and somewhat likely. The three introductory
activities she reported as very unlikely to use were to describe the relationship students will observe between the mass at the end of a spring and the period of its bounce, to define the word “variable” and ask students to identify variables in the spring investigation, and to explain the procedure for using Punnett squares, all other than inquiry-oriented options.

On the section of questions that asks how the teacher will respond to students who have made mistakes or have misconceptions, the teacher in classroom 3 responded with a total average of 2.3 with more inquiry-oriented options receiving an average of 3 and other options averaging 2.1, indicating that when handling student errors she is more likely to use inquiry-oriented responses. Two of the choices call the attention of the whole class to the student’s error; classroom teacher 3 rated those as 1, very unlikely choices for her.

The third set of questions asks teachers to respond to different ways of handling student disagreements about the phenomena under study. Classroom 3’s teacher rated the choices that were more inquiry-oriented higher, an average of 3.3, than the other choices, an average of 2.1, indicating she would be somewhat unlikely to use less inquiry-oriented choices. The total average for this set of questions was 2.5. In this section she was very unlikely to use the response options that show students the formula for the period of a spring’s bounce, in which mass, but not distance stretched, affects the period and explain that the second group is correct because over time hybrids will mate with hybrids.

The last set of questions asks for how much emphasis the teacher would place on different learning objectives specific to the scenarios, some more inquiry-oriented than
others. As shown in Table 13 the teacher’s total average was 3.1 with inquiry-oriented responses averaging 2.6 and the other options averaging higher at 3.3, showing a propensity toward less emphasis on inquiry-oriented learning objectives and a moderate emphasis on all the options inquiry-based or otherwise. Of all of classroom teacher 3’s responses on the RAND survey in both sections of questions asking about what learning objectives she would focus on, either with her own content or with the scenario content, she chose options that were less inquiry-oriented more often than options that were more inquiry-oriented, as shown in Figure 10.

To compare teachers’ theoretical attitudes toward inquiry based science teaching, classrooms were observed using the Essential Features of Classroom Inquiry. Narrative descriptions were recorded during observations to provide a voice. Figure 8 shows the mean of each component of the Essential Features for the four observations done in Classroom 3. During one of the four visits to classroom 3 students were reading, taking notes, drawing pictures, and constructing a model of the features on the ocean floor, so they were not engaged in any of the components of the Essential Features of Classroom Inquiry during that class period which had an effect on the rating of each component. The highest rating possible for each component was a 4, representing the most learner self-direction and the least amount of direction from the teacher or the material. A zero was used for not observed. So a classroom that was most inquiry-based would have an average of 4 for each component.

There are five components to the Essential Features observation protocol. The first concerns the learner posing their own testable question, more learner self-direction,
on a continuum to the learner engaging in a question provided for them either by the teacher or the materials, less learner self-direction. The mean of students posing their own questions was 0.5, having observed students engaged in questions provided by the teacher, materials, or other sources twice over the four observations in classroom 3. On one occasion students were explicitly given the question; what is the relationship between ocean layers, density, and salinity? On the other occasion students were given two balloons and a equal arm balance with the purpose of proving that air has mass and identify the layers of the atmosphere. A student asked, “How are we going to prove it?” The teacher responded, “That’s your task, with the materials, you are going to prove it?

Figure 11. Mean of each Component of the Essential Features of Classroom Inquiry for Classroom 3
In both instances students were involved in trial and error problem-solving, so questioning was inherent in the activity but students were still focused on a question given them.

During two observations of classroom 3 students were directed to collect certain data by being given data collection organizers. During a water cycle activity students trimmed and glued a data collection sheet into their science notebooks and recorded their locations in the water cycle by completing sentence frames. During another activity students were given a FOSS data sheet that they also glued into their science notebooks and then recorded their attempts at stacking liquids with different densities, noting how the solutions layered. Students during another investigation, on the other hand, came up with their own data collection system when they were asked to prove whether or not air had mass. These observations gave classroom 3 a rating of 2.5 of 4 for the component of giving priority to evidence in responding to questions.

The third component, students formulating explanations from evidence, was rated a mean of 0.75. During the investigation of the frequency that students were located in different areas of the water cycle, the teacher guided a class discussion asking, “Why would most people end up in the atmosphere?” The only time the use of a claim and evidence chart was observed was during the air has mass investigation. The teacher guided students in writing a claim/evidence chart in their science notebook, listed the claim for students as air has mass, and directed students to complete “at least two pieces of evidence from our activity.”
The learner connects explanations to scientific knowledge rated a mean of 1.25 as shown in Figure 8. This component was not observed during two classroom visits. During the other two classroom observations, in one instance, students were referred to a pie chart showing the percentage of the earth made up of oceans when asked why most people would end up in the atmosphere. In the other instance, students were told the possible connection in the following exchange:

Teacher: “Where was the red?”
Student: “At the top.”
Teacher: “Right because it had more salinity, density.”

The last component of the Essential Features protocol is the degree to which students communicate and justify their explanations. This area rated a mean of 1.5. Observations of this component were recorded during three of the four visits to classroom 3. The most note worthy was during the first observation visit when students’ learning target was to understand the availability of water in water movement. After students followed the activity of rolling number cubes to determine where they landed in the water cycle, students were directed to represent their findings with the teacher asking, “How do you want to show the data?” Students then chose how to communicate their data, in a table or graph; pie chart, line graph, frequency table, bar graph to name a few. When students completed this in their science notebook, they presented their findings to the class using the visualizer. The teacher asked, “What can you conclude? I want you to listen to each other.”
During two other observations students were given the steps and procedures for communicating their results. After the stacking liquids activity students answered questions at the bottom of the FOSS data sheet that students had glued into their notebooks. After students investigated the mass of air the teacher guided students in writing in their science notebook. She labeled a section “Results”, then measured the mass of an empty balloon and the mass of the same balloon blown up on a digital scale and modeled how to put that information in a T-chart. In this same section the teacher drew a T-chart with claims one side and evidence of the other side and wrote, “air has mass” under the claim. She directed students to write two pieces of evidence on their charts under evidence.

Teachers also completed the CLES 2(20) which uses a 5-point Likert scale with responses ranging from almost never to almost always, in order to determine whether the classroom is more constructivist and student-centered, or whether the classroom is less constructivist and teacher-centered. A mean of 5 suggests the ideal constructivist classroom and classroom teacher 3 indicated with a mean of 4 that her class is often constructivist in nature (see Table 14). Again the CLES scale for uncertainty had the

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Relevance/ Learning about the World</td>
<td>3.75</td>
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<tr>
<td>Uncertainty/ Learning about Science</td>
<td>3.25</td>
</tr>
<tr>
<td>Critical Voice/ Learning to Speak Out</td>
<td>5</td>
</tr>
<tr>
<td>Shared Control/ Learning to Learn</td>
<td>4</td>
</tr>
<tr>
<td>Student Negotiation/ Learning to Communicate</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4</strong></td>
</tr>
</tbody>
</table>
lowest mean with 3.25, responding seldom to two descriptors; students learn that science
cannot always provide answers to problems and students learn that science is influenced
by people’s cultural values and opinions. She rated the CLES scale critical voice a 5,
suggesting that students feel safe to question, to ask for clarification, and to express
concern about anything that gets in the way of their learning.

The researcher attempted to identify the constructivist scales in action in
classroom 3 from the classroom narrative in order to associate the theoretical responses
from the teacher to what might be present in the classroom on a daily basis. A part of
personal relevance concerns how students’ new learning relates to current experiences. In
classroom 3 when students were trying to answer the question of whether air has mass or
not, one student was telling another student, “You have to look very closely,” referring to
the equal arm balance. Knowing how to use and read an equal arm balance was not
relevant to the student until faced with the problem of finding the mass of air. Uncertainty
was experienced during this same observation because students were given intentionally
vague directions to the task. The teacher wanted students to design their own procedures.
One student responded, “How do we know how much the air weighs if we don’t know
what the balloon weighs?”

No observations were made concerning critical voice. However, students seemed
comfortable in asking questions of the teacher, both general questions and clarifying
questions. In considering the scale shared control, during two lessons in classroom 3 it
was observed that at some point in the lesson, students were given complete control in
either how they represented their learning, during the water cycle investigation, or how they approached a problem, during the air has mass investigation.

The final scale on the CLES is student negotiation in which students are communicating and learning from one another. Several observations made during the three of the four visits to classroom 3 exemplified this scale. At the end of the water cycle activity, students shared their data representations to the class. The teacher asked, “What can you conclude?” When students were layering liquids with different densities students were in constant negotiation: sharing their observations, revising their trials, explaining their thinking about what they were observing, and planning their next trial. During the very open-ended investigation of air and mass, students were heard saying, “Blow a little air in one balloon and more in the other and check the difference.” “Blow up balloon . . .” to other students in his group. One student asking clarifying questions about gravity and air of another student in his group. One student to another, “You have to look very closely,” telling him how to use the equal arm balance. And later in the lesson a disagreement about gravity and air whether they are working together for weight, “No, gravity doesn’t have . . .”

Classroom 4.

Classroom 4 was a third grade self-contained class that received science instruction in a 30 minute time frame daily until the end of the unit then students would receive social studies instruction during the same frame. Only two observations were made in classroom 4, both times students were moving from working in table groups of four to six students to meeting on the floor at the front of the class for whole group
instruction and back to working in table groups for investigations. The class appears to be well balanced for gender, ethnicity, and ability. The teacher reported that 15% of her students were ELL students. She is White (not of Hispanic origin) and holds a master’s degree. As an undergraduate student she did not major in science, but she did earn a minor in science or a science intensive field. Including this past school year, 2011-2012, she has taught eleven years and has ten years experience teaching science. This was, however, only her second year teaching third grade. She has not served as a lead teacher, but reports feeling moderately confident in teaching the content she is asked to teach.

At the beginning of the RAND survey general questions are asked about what emphasis teachers put on different learning objectives, teaching strategies, and student activities when thinking about the content they teach. Classroom teacher 4 chose more inquiry-oriented options than options indicating less inquiry. Her total mean for question 4 was 3.1 with inquiry-oriented choices averaging 3.75 on a 4-point Likert scale and other options averaging 2.75 (see Table 15 and Figure 12), suggesting that classroom teacher 4 would lean toward being more inquiry-oriented. Options that would get only a slight emphasis were constructing and using models and identifying independent and dependent variables in an investigation. None of the options would get no emphasis.

When choosing teaching strategies teacher 4 would use all but one option almost every day with encouraging students to consider alternative explanations used once or twice a week. Question 6 asked how often students would engage in different activities, the average of all the choices was 3.5 on a 5-point Likert scale ranging from never to almost every day. For the inquiry-oriented choices, like engage in hands-on science and
share ideas and problem-solve with peers, the average response was 3.75; she would ask students to engage in hand-on science activities almost every day, but working on extended science investigations would only happen a few times a year. The mean for

Table 15
Classroom 4 Teacher Mean Response Scores on the RAND Survey of Instructional Choices

<table>
<thead>
<tr>
<th>RAND Survey Questions</th>
<th>Total</th>
<th>Inquiry-oriented</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Emphasis on Learning Objectives</td>
<td>3.1</td>
<td>3.75</td>
<td>2.75</td>
</tr>
<tr>
<td>5. Teaching Strategies&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.8</td>
<td>4.75</td>
<td>5</td>
</tr>
<tr>
<td>6. Student Activities&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.5</td>
<td>3.75</td>
<td>3.25</td>
</tr>
<tr>
<td>8/12 Introductory Activities</td>
<td>2.5</td>
<td>3.2</td>
<td>2.1</td>
</tr>
<tr>
<td>9/13 Response to Student Error</td>
<td>2.9</td>
<td>3</td>
<td>2.9</td>
</tr>
<tr>
<td>10/14 Differing Explanations</td>
<td>2.7</td>
<td>3</td>
<td>2.6</td>
</tr>
<tr>
<td>11/15 Emphasis on Learning Objectives</td>
<td>3.4</td>
<td>3.8</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Note. <sup>a</sup>These means are on a 5-point Likert scale. The rest of the table is based on a 4-point Likert scale.

other options besides inquiry-oriented was 3.25. Again, working on extended investigations was rated the lowest.

The remaining survey questions ask teachers to respond to information about two mythical classes and put themselves in the position of the teacher in each class. Response choices are on a 4-point Likert scale, ranging from very unlikely to very likely. The first set of questions in each scenario asks the teacher how likely they are to use different strategies to introduce the unit of study. The teacher in classroom 4 responded with an average of 2.5 with inquiry-oriented strategies outweighing other strategies with a mean of 3.2 compared to a mean of 2.1. She would be very unlikely to introduce the unit by
asking students to give examples of how springs are used in their everyday lives or by explaining the procedure for using a Punnett square.

The second set of scenario questions ask how teachers might respond to students’ errors. As shown in Table 15 the teacher in classroom 4 shows no difference between more inquiry-oriented responses and less inquiry-oriented responses. The mean for inquiry-oriented options was 3 while the mean for other options was 2.9. The mean of the total was also 2.9, suggesting she was equally likely to respond in a inquiry-oriented way as to other than inquiry-oriented. There was also little difference in her responses on the third group of questions pertaining to students’ differing explanations. She was very likely to indicate that these are both interesting observations and continue with the lesson, the only response she rated a 4. Inquiry-oriented options had a mean of 3; the teacher of
classroom 4 responded with a 3 on every choice that was inquiry-oriented, options that ask students to explain their thinking and agree or disagree with one another. Other options had a mean of 2.6 indicating she was torn between somewhat unlikely and somewhat likely.

Classroom 4’s teacher was more likely to emphasize inquiry-oriented learning objectives with a mean of 3.8 of 4 than other learning objectives which had a mean of 3.1. As shown in Table 15 the mean of this set of questions was 3.4. None of the options for learning objectives were rated below moderate emphasis. Students will be able to design their own experiments was the only inquiry-oriented option that was not rated as one the teacher would give great emphasis.

Overall, the teacher in classroom 4 would more likely choose introductory activities that are more inquiry-based. Shown in Figure 12 she would also be more likely to emphasize learning objectives that are also more inquiry-oriented than not inquiry-oriented. The teaching strategies that she currently uses are slightly more likely to be other than inquiry-oriented.

Classroom 4 was only observed two times during the data collection period, so it’s possible that the description of that class is not as complete as it could have been with more observations. Narrative descriptions were added during observations to provide a voice. Figure 9 shows the mean of each component of the Essential Features for the two observations. The highest rating possible for each component was a 4 with a zero used for not observed. So a classroom that was most inquiry-based would have an average of 4 for each component.
The first of five components of the Essential Features of Classroom Inquiry pertains to how students engage in scientifically oriented questions. Classroom 4 was rated a 1. On one visit students were sharpening or clarifying a questions provided by their teacher or the FOSS kit, Water. The teacher guided students in thinking about a question for the day’s investigation by saying, “I want you to observe the surface tension of the soapy water. What do you look for?” A student responded, “What happens when you put soapy water?” Posted in one area of the room were four charts one for each of the following: questions, vocabulary, properties, and observations. It was clear that information had periodically been added from each of the students’ experiences, there
were a number of questions listed as well as vocabulary words, properties of water that students had discovered and observations they had made. Questioning was not observed on the next classroom visit.

The students in classroom 4 were given opportunities to either determine what constitutes evidence and then collect it or were directed to collect certain data, rating a mean of 3.5 of 4 for the two observations. While exploring soapy water students were putting drops onto a penny using a pipette. In their science notebooks some students were counting and recording the number of drops the penny could hold, but some didn’t want to, they wrote out their observations and descriptions. During the second observation classroom 4 was exploring the water cycle by using number cubes to determine where in the water cycle they were located. Students were directed to write the name of the location after each roll of the number cube.

During both classroom visits students were given possible ways to use evidence to formulate explanations. During the first observation the teacher tried to elicit an explanation with a series of questions, following a FOSS script and trying to get students to use the phrase surface tension.

Teacher: “Why did the water go right to the edge?”

Student: “As we add drops the bead expanded.”

Teacher: “What did it look like – kind of like a dome?”

Student: “Water sticks together.”

Teacher: “. . . shell of the outside of the bubble.”

Student: “. . . shell expanded the surface.”
In the middle of collecting data through the water cycle activity the teacher asked, Why do you think a lot of us are in the clouds?” A student responded, “Water evaporates into the clouds.” At the end of the activity the teacher called students to the carpet at the front of the room with their science notebooks and a pencil. She asked, “Where did you end in an awful lot?” Students informally shared their results with the class.

The component that relates to connecting to scientific knowledge rated a 1.5 for the two observations. During the investigation of the water cycle students were guided by the teacher in connecting back to their previous learning by reminding students of conclusions they made during prior investigations and putting adhesive notes on a large diagram of the water cycle. The last component, students communicating their explanations were not observed on either day, resulting in a rating of zero.

The second survey teachers completed was the CLES 2(20) which uses a 5-point Likert scale, scaled from almost never to almost always, so means shown on Table 16 are compared to 5, environments that are the most constructivist or student-centered. For teacher 4 the scale that was the least constructivist/student-centered was the one addressing shared control of students’ learning environment in which none of the questions were rated higher than sometimes. At the same time, she did not rate any of the questions at 1, almost never. The scale that measures critical voice, how often students are able to speak out, ask for clarification, express concern, and freedom to ask question, rated the highest with a mean score of 4.25, more than often leaning toward almost always.
The researcher attempted to identify the constructivist scales in action in classroom 4 from the classroom narrative in order to associate the theoretical responses.

Table 16

Classroom 4 Teacher Mean Response Scores on the CLES 2(20)

<table>
<thead>
<tr>
<th>Scale</th>
<th>Mean</th>
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</thead>
<tbody>
<tr>
<td>Personal Relevance/ Learning about the World</td>
<td>3</td>
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<tr>
<td>Uncertainty/ Learning about Science</td>
<td>3.25</td>
</tr>
<tr>
<td>Critical Voice/ Learning to Speak Out</td>
<td>4.25</td>
</tr>
<tr>
<td>Shared Control/ Learning to Learn</td>
<td>2.5</td>
</tr>
<tr>
<td>Student Negotiation/ Learning to Communicate</td>
<td>3.75</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3.35</strong></td>
</tr>
</tbody>
</table>

from the teacher to what might be present in the classroom on a daily basis. The only scale of the CLES that was evident during the two observations was student negotiation. During the observation of students dropping soapy water on a penny, students were very engaged in the activity and with their group. Discussions within groups of students were centered on how to record the count of drops, how to use the pipettes to get the most drops on the penny, and asking each other what would happen if questions.
Chapter Five: Discussion

Introduction

School D was initially chosen for this study because of its eighth grade science CSAP scores in 2009. Table 17 shows phenomenal results that year with that group of eighth graders. There was no gap between science achievement for students of color compared to their Anglo peers, and students receiving federal lunch support had the same percent of students proficient as the total eighth grade. Looking at the eighth grade scores in 2009, it was hypothesized that School D would be an example of a high level of inquiry-oriented instruction and it could be observed and documented how high levels of inquiry-based instruction translates into the classroom and the school. Table 17 shows clearly that the group of eighth graders in 2009 was an anomaly for School D and, in fact, an outlier in the state, a school in which there was no achievement gap and over 70% of all students were proficient or higher. Scores prior to 2009 went from 44% proficient in 2007, the first group of eighth graders, to 58% proficiency in 2008 and after 2009 47% of the students in 2010 were proficient and 38% were proficient in 2011.

Scores for every group at the eighth grade level except White students dropped considerably in 2010; most notably the percent of Hispanic students that were proficient dropped 40%. In 2011 the proficiency of White students dropped nearly 30% from 2009 with 45% proficient down from 71%. Even with the decrease in the percent of students attaining proficiency in 2010, eighth graders at School D were just shy of the state total
and Black, Hispanic, and students who qualified for free/reduced lunch outperformed students in the state in the same groups. The percent of proficient eighth graders in every group went down on the 2011 science CSAP, but students who represented Black students and those qualifying for free/reduced lunch still outperformed students in these same groups statewide, and showed little difference between the total and White students.

Table 17

Percent of Students Performing at the Proficient or Advanced Level on the Colorado Student Assessment Program (CSAP) at the Fifth and Eighth Grade

<table>
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<tr>
<th></th>
<th>5th Grade</th>
<th></th>
<th>8th Grade</th>
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<tbody>
<tr>
<td></td>
<td>State</td>
<td>District</td>
<td>School</td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>45</td>
<td>23</td>
<td>31</td>
</tr>
<tr>
<td>White</td>
<td>58</td>
<td>45</td>
<td>38</td>
</tr>
<tr>
<td>Hispanic</td>
<td>21</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>Black</td>
<td>24</td>
<td>18</td>
<td>24</td>
</tr>
<tr>
<td>Free/Reduced Lunch</td>
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<td>40</td>
<td>21</td>
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<tr>
<td>Total</td>
<td>47</td>
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<td>63</td>
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<tr>
<td>White</td>
<td>61</td>
<td>44</td>
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<tr>
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</table>

Note. Data for this table was retrieved from the Colorado Department of Education, Unit of Student Assessment Website, January 22, 2012

Another anomalous group of students shown on Table 17 were those that took the fifth grade science CSAP in 2010. Students in every group that year out scored students
in these same groups in 2009 and 2011. The percent of fifth graders who were proficient school-wide was 63% in 2010, nearly twice that of the percent of students proficient in 2009, 31%, and 2011, 32%. In 2010 the percent of Hispanic students proficient nearly matched that of the total fifth grade with 60%.

The achievement gaps in the fifth grade in 2011 were very small with one exception. Only 19% of African American fifth graders were proficient while the percent proficient for all the fifth graders was 32% a difference of 13%. Hispanic students were just above the school total and students receiving free/reduced lunches were just under the school total. The scores for eighth graders in 2011 also showed very little difference in performance between groups of students. Even though White students performed below their peers at the state and district level with only 45% of the students proficient, African American students outperformed their peers in the district by 14% and in the state by 7% and students eligible for free or reduced lunches outperformed their peers in the state by 11%.

Even though School D did not maintain the initial criteria in the years after 2009 there is still value in this case study. During school year 2011-2012 ethnic/racial minorities were the majority, 62%, at this school with Hispanic students making up the largest percentage of traditional underserved students. Even though the science CSAP scores for fifth and eighth graders in 2011 were low across the board, the differences in proficiency between groups of students were much smaller than those at the state and district levels, both at the fifth and eighth grade.
Inquiry-based instruction is a continuum from very teacher-centered to highly student-centered, from traditional to reform (Anderson, 2002). However, in *Taking science to school: Learning and teaching science in grades K-8* the point is made that “Instead of pure discovery or pure direct instruction, students need strategic ‘scaffolds’ that embed instructional guidance in ongoing investigations” (National Research Council, 2007, p. 272). Abrams, Southerland, and Evans (2008) define levels of inquiry from level 0, completely teacher directed to level 3, completely student directed. Blanchard et al. (2010) compared guided-inquiry, level 2, to verification, level 0, and found that it was at the guided level that traditionally underserved students performed better in science. The focus of this discussion then will be on the continuum of inquiry and what School D is doing to foster a minimal gap between groups in science achievement. So the original question remains:

What are the instructional choices, classroom environments, interventions, and school practices in place in one K-8 school that is supporting traditionally underserved populations of students in the learning of science?

However, since schools operate within a context of the district and school. It became apparent that this school faced some challenges in terms of the district curriculum and the district and school’s practices around professional development. It was impossible to exclude these issues from a complete understanding of this case study.

**Science Curriculum: Alignment to State Standards**

One of the elements of a strong science program is its science curriculum and how well that curriculum is anchored on a foundation and aimed toward a recognized set of
standards. Even though Colorado does not have a state science curriculum, it does however, have a very specific set of standards that detail what students should know and be able to do; and every fifth, eighth, and tenth grader in the state is required to take the CSAP, now the TCAP, and be proficient on that state assessment. Research has shown that schools that are laser focused on common goals, anchored on state and national standards, outperform schools that are not, regardless of the ethnic/racial minority makeup or poverty level of the school (Barth et al., 1999; Fullan et al., 2006; Haycock, 2001; Reeves, 2002; Schmoker, 1996; Schmoker, 2001; Schmoker, 2006).

The pacing guides for secondary science, grade six through high school, are very detailed. Referring to Appendix E one can see that the content taught and the specific units to be taught at each grade level for each quarter are listed. At sixth grade units are from the earth science standard, at seventh grade they are from life science, and at eighth grade they are from physical science with the specific topics that relate directly to the benchmarks described in the 2007 content standards document clearly listed for each quarter. The implications are that when students took the science CSAP in eighth grade they had had no earth science for two years and no life science for one.

When accessing the middle level pacing guides, written in 2008, from the division of instruction web page, one will notice that included for each unit of instruction are the specific benchmark, copied directly from the *Colorado content standards: Science*, learning goals, what students should know, understand, and be able to do, inquiry lessons and labs, and resources. When one looks more closely at the activities under inquiry lessons, it becomes apparent that these are not truly inquiry as defined in the research
(Anderson, 2002; Bybee, 2006; NRC, 2000; NRC, 2007). Inquiry lessons listed for sixth grade include, for example, students can research and draw diagrams of the water cycle and create word walls linked to student writing and Liquid Rainbow, an activity to layer water with different amounts of salt dissolved in it. At the eighth grade, inquiry lessons include create, label, and color an electromagnetic spectrum using information from the textbook, demo light waves interacting with matter to transfer energy with a radiometer, and investigate alternative energy. The last is the only one listed that lends itself to an inquiry investigation, depending on how student-centered the lesson is organized.

During the span of classroom visits to the eighth grade class, instruction in conservation of energy, energy transformations, and light were observed, listed on the third quarter pacing guide for eighth grade. Classroom teacher 1 was very focused on the district pacing guide for eighth grade. At the beginning of each new unit she gave students a topic sheet that students would glue into their science notebook. Each topic sheet included the Colorado state standards and benchmarks for the unit, the learning goals; at the end of this unit I should be able to . . ., activities and labs that students will do, including labs, notes, and assessments, and resources, including textbook pages and websites. Students were working on the benchmarks related to energy transformations. She posted the learning target on the board at the front of the room each day. The following learning targets are listed in the order they were observed:

- LT: I will investigate how energy changes from one form to another
- LT: I will investigate how mass, length, height affect a pendulum swing
LT: I will investigate how waves transfer energy

Each learning target was directly related to a state physical science benchmark.

Students in Classroom 3 were learning about Earth’s waters and on the last observation of this class students began their study of weather, exactly what is listed for third quarter on the sixth grade pacing guide. The following learning targets were directly related to the sixth grade pacing guide; and were posted at the front of the classroom and changed daily:

LT: I will understand the availability of water in water movement
LT: I will understand the characteristics of the ocean floor and the ocean water
LT: I will understand the physical characteristics of ocean water
LT: I will prove that air has mass and identify the layers of the atmosphere

During the last classroom observation the teacher showed students the page from the district pacing guide that students would be focused on in the next few lessons. She was pointing out what students would know and be able to do in relation to the layers of the atmosphere:

Students should know:
- The Earth’s atmosphere supports life
- Density and temperature change with altitude.
- The layers of the atmosphere are:
  - troposphere
  - stratosphere
  - mesosphere
  - thermosphere

Students should understand:
- Air has mass
- As you move up in the atmosphere the density of air particles decreases

Students should be able to:
- Identify the order of the layers of the atmosphere
- Describe or identify individual characteristics of each atmospheric layer

These are much more detailed than the state standard for this topic: Benchmark 4.7 the atmosphere has basic composition, properties, and structure (for example: the range and distribution of temperature and pressure in the troposphere and stratosphere; Colorado Department of Education, 2007, p. 12). But, they are also very low on Bloom’s taxonomy, at the knowledge level, asking students to memorize information.

Glatthorn (2000) makes the point that a district’s curriculum needs to be tightly aligned with the state curriculum frameworks. The lessons observed in Classroom 2 and 4 aligned perfectly with the district pacing guides for each grade. The fifth grade class, Classroom 2, was working from the FOSS kit Mixtures and Solutions, listed on the district pacing guide for fifth grade. In the third grade class, Classroom 4, science instruction was from the FOSS kit Water which is listed on the district pacing guide for third grade. However, in analyzing the alignment of school to district to state curricula there were some noticeable disconnects, particularly at the elementary level.

The elementary, K-5, curriculum in District 4 is a loose collection of kits, primarily Full Option Science System (FOSS) kits. The online elementary pacing guide details which three kits will be taught at each grade level and which school starts with each kit, but there is no scope and sequence chart aiming teachers toward the state framework for science. There is nothing that defines the science content that students in Kindergarten through fifth grade are supposed to come away with and move to the middle level with. Teachers are then left guessing about how to focus instruction.
Teachers can connect to FOSSweb through the hyperlinks on the pacing guide to access teacher resources for each unit. Looking at a number of unit links, FOSS has articulated inquiry goals for each unit, but the science content objectives are vague and less concrete. For example the FOSS Water kit, taught at third grade, and the Mixtures and Solutions kit, taught at fifth grade, explicitly state the inquiry goals of asking and answering students’ questions, planning and conducting investigations, using tools to gather data, constructing reasonable explanations, and communicating about their investigations and explanations, supporting inquiry-based science as described by the *NSES* and others (Karplus, 2002; Magnusson & Palincsar, 2005; National Research Council, 1996; National Research Council, 2000; National Research Council, 2007; Rutherford & Ahlgren, 1990; Yager, 2004).

The content objectives for the FOSS Water kit, taught at third grade, however are much too vague. One such objective is to develop students’ understanding of the properties of earth materials, including rocks, soil, water, and the gases of the atmosphere. Also included content objectives are the ideas that clouds affect weather and climate, that soils have properties and can retain water, and that water moves in the water cycle (The Regents of the University of California, 2008). These are all addressed in four investigations. Looking at the synopsis of each of the four investigations, it’s difficult to connect these objectives to specific third through fifth grade science content standards or benchmarks described in the *Colorado model content standards: Science*. After observing Classroom 4 two benchmarks for third through fifth grade that could possibly be connected to the FOSS Water kit were found:
Benchmark 2. 2 measurable physical properties can be compared before and after effecting a change to verify a change has occurred and used to predict its outcome in similar circumstances (p. 7).

Benchmark 4. 6 water exists on Earth in different states (solid, liquid, gas) and changes from one state to another (for example: evaporation, condensation and precipitation; p. 11).

It was not evident that the teacher observed was aiming for these particular benchmarks. She was struggling to get students to the phrase “surface tension” rather than emphasizing the change in the number of drops that students observed. The teacher asked a number of leading questions, attempting to get students to be aware of and use the term “surface tension”. Would students have connected better to a third grade friendly benchmark statement related to: measurable physical properties can be compared before and after effecting a change to verify a change has occurred? During this lesson students were comparing the number of plain water drops that a penny could hold to the number of soapy water drops on a penny; clearly students had an opportunity to verify that a change had occurred.

The content standards for the FOSS Mixtures and Solutions kit include substances have characteristic properties such as solubility and mixtures can be separated into original substances using their properties. Another is that substances react chemically with other substances to form new substances and that there are over 100 known elements that combine and make compounds. The four investigations, however, are focused on separating mixtures, saturation levels, concentration of mixtures, and chemical reactions (The Regents of the University of California, 2008). When attempting to compare these objectives to the benchmarks in *Colorado model content standards: Science* none were
found for third through fifth grade. One, however, was found at the K-2 level;

“Benchmark 2.2 mixtures can be created and separated based on physical properties (for example: salt and sand, iron filings and soil, oil and water)” (p. 7). And, one was found at the 6-8 level; “Benchmark 2.2 mixtures of substances can be separated based on their properties (for example: solubilities, boiling points, magnetic properties, densities and specific heat)” (p. 7). While observing Classroom 2 it was evident that the following 3-5 benchmarks were also addressed even though they were not explicitly stated:

- Benchmark 2.1 objects have physical properties that can be measured (for example: length, mass, volume and temperature)
- Benchmark 2.2 measurable physical properties can be compared before and after effecting a change to verify a change has occurred and used to predict its outcome in similar circumstances (p. 7).

In Classroom 2 the learning target (LT) for the day was posted at the front of the classroom. During the first two observations the following was posted:

LT: We are looking at saturation of a solution to explain the properties of solids

On the third observation the following learning target was posted:

LT: We are looking at precise scientific procedures that best answer our question

Neither one of these learning targets address a benchmark nor learning goal from the state standards document, *Colorado model content standards: Science*, for any grade span.

Was the teacher in Classroom 2 aware of the benchmarks she was addressing? And if so, why were they not the focus of each class period?

Classroom teachers 2 and 4 were focused on goals from the FOSS kits, but those goals and targets did not align with this state’s grades 3-5 standards for science from 2007. Glatthorn (2000) states, “[T]he text should serve the curriculum and not drive it”
(p. 41). In this case the FOSS kits, materials, and textbooks are driving the K-5 science curriculum in District 4. The teachers in Classrooms 2 and 4 were conscientiously following the teacher guides and using the materials from FOSS as they understood them and, in fact, they were following the district science curriculum.

Each FOSS kit has four sections of investigations, covering different science ideas. How are individual teachers to decide what to focus on when the curriculum guide simply lists a kit name, Water or Mixtures and Solutions to name two? Those decisions need to be made similarly as one would make in using a textbook, choose the sections or activities that will support students in learning the targeted standard (Bybee, 1997; Kulm et al., 1999; National Research Council, 2007). What’s needed is a set of coherent, specific, age-appropriate student learning goals that the district has identified as essential science content understandings aligned with state science standards (Glatthorn, 2000; Marzano, 2003; National Research Council, 2007; Vasquez, 2008).

**Resources Allocated for Science Instruction**

“Nothing interferes with inquiry-based teaching more than lacking an adequate supply of instructional materials” (National Research Council, 2000, p. 149). This does not, however, apply to School D. They have an excess of hands-on materials, adequate time, and highly qualified science teachers to devote to high quality science instruction.

**Facilities and materials.**

School D is a relatively new school and as part of its new school budget they were able to fully supply the science program. The principal said this, “With new school budget, they were really able to stock up. We have space that’s dedicated to science, and
we have materials that are dedicated to science, we have equipment that’s new, functioning”. The school was built with two fully outfitted, dedicated science classrooms, the seventh/eighth teacher is in one and the other is available when needed for other grades. The other science classrooms that were observed all had sinks built into the room, even the third grade classroom.

To support all students they used their new school budget to fully stock up on science kits; more than thirteen FOSS kits, thirteen Science and Technology for Children (STC) kits, and three other kits were observed in the science supply room between the two science classrooms. All four teachers surveyed report having the following fully available; balances and spring scales, glassware such as beakers, graduated cylinders, etc., thermometers, metric rulers, water for experiments, and rocks, sand, and minerals. Two of the four reported having microscopes, stop watches, and probe ware (e.g. motion detectors, temperature, and salinity) partially available instead of fully available and one teacher did not know about the availability of chemical reagents, however these were observed in the science supply room. The principal shares her commitment to science, “If my general budget couldn’t cover something and I knew that our kids need that to learn and our teachers need that to teach, I would find the money for it somewhere else”. In every classroom observed, during every observation, students were using either FOSS kits or components of FOSS kits in addition to other material resources. Bredderman’s (1983) meta-analysis found that “disadvantaged students derived greater benefits than other students” (p. 499) in using hands-on materials to learn science content, so the students at School D are well supplied and have lots of opportunities to do science.
**Time for science instruction.**

Until recently School D has had the luxury of giving the same amount of time to the science program as they have to the math and literacy programs. This was nearly twice what other students in the district were getting. The fifth through eighth grade were on a block schedule so each class was 105 minutes long. This required more teachers teaching science; and due to budget cuts at the district, the school had to cut their time for science in half. Since school year 2008-2009 students have averaged 250 minutes per week for the year instead of 525 minutes per week. So instead of getting science every day, students in sixth grade were getting science every other day and fifth, seventh and eighth grade students were getting science every other quarter. The *NSES* promotes the idea that students are allocated time in the school program for science every day, every week, and every year (National Research Council, 1996, p. 219). Classroom teacher 1 stated, “When [students] come back after a quarter off they don’t remember anything. It’s like first quarter never happened. In eighth grade everything builds off each other. I’ve done so much re-teaching”. Not only did this possibly impact their science CSAP scores but it most likely affected the district interim scores. According to the principal,

> We’ve had to get creative about the interim assessments. Kids might be taking an interim on content that they haven’t had since the first quarter. [And how have you done that?] We have had to review the schedule in terms of test taking; it’s not optimum for example, eighth grade is taking science first quarter and third quarter, they are still following the pacing guide they are not cut any content, but it’s not fresh for them and then in second quarter when the district says this is when we are taking the interim assessment, they had that content first quarter.

Bybee (1996) says that science programs should “allow adequate time and opportunities for students to formulate knowledge, skills and attitudes” (p. 46). School D has lost some
of those opportunities. When students are only getting one semester of science split over
the year there is no continuity of instruction. The science program at the sixth grade
makes more sense in that students have a more continuous science program when they
are in science class every other day instead of every other quarter.

Highly-qualified science teachers.

The four teachers observed and surveyed were all highly-qualified and
experienced educators, a great asset for School D. All four teachers reported being fully
certified to teach in Colorado and one teacher holds a specific certificate or endorsement
for teaching science. Two of the four science teachers majored in science as
undergraduate students; one of these also minored in a science related field. A third
teacher minored in science as an undergraduate but did not major in science and the
fourth had no degree in science. Three of the four reported having master’s degrees; one
of whom had more than one. The number of total years teaching ranged from seven years
at the low end to seventeen years being the most experienced, averaging 11.25 years of
overall teaching experience. Experience teaching science ranged from three years to a
high of ten years, averaging 6.25 years and teachers reported an average 4.5 years
teaching the grade level that was under observation. Numerous studies have shown that
students with teachers who are fully certified, have at least three years of experience, and
have a degree in their content area are more likely to score higher on national and state
assessments (Akiba, LeTendre, & Scribner, 2007; Darling-Hammond, 1999; Darling-
Science Focused Professional Development

Laissez-Faire might best summarize the district and therefore the school’s, attitude about science related professional development. In the principal’s words:

One of our root causes that teachers have identified is that we don’t, especially at the elementary level; teachers are reporting that they don’t have that strong content knowledge in science and I can’t say that we have done much to be able to improve that. I don’t feel like we’ve got our stride with the district coach with whom we are working with to really get that content knowledge through professional development.

Researcher: How is it that science teachers can work together across the building?

Principal: There are spotty opportunities for this. Quite frankly, we are working on our major improvement strategies.

Researcher: You don’t have a chance to work on science?

Principal: [Building-wide professional development is] not dedicated to that.

Researcher: So, science teachers have a real limited time or opportunity to meet together across grade levels?

Principal: There’s opportunity within their own planning; on the days we are not meeting they all have from 2:30 to 3:30 for their own instructional planning time that they could. I would say it happens more during grade level planning then specifically with just all teachers about science. I don’t feel as though it is well defined. I would like to see some different support from our teacher/district coach in terms of helping to foster that, but it just hasn’t gelled.

The exchange above illustrates the fact that science teachers are left with no structure to frame building science professional development and there is an expectation the district will provide all that’s needed for science professional development.

Northouse (2004) describes Laissez-Faire leadership as one that “makes little effort to help followers satisfy their needs. There is no exchange with followers or any attempt to help them grow” (p. 179). However, it is possible that what looks like Laissez-
Faire on the part of the principal is hiding the sense of not knowing what to do to improve
science instruction; and therefore, what is needed is a focus on building the capacity of all
parties. This was expressed differently by the science teacher leader, “Honestly I just
wore the title, nobody ever asked for anything, so I got a block off; a huge waste of
resource, and time and money, I think”. What if she were provided with opportunities to
increase her capacity to work with other science teachers in her building; and with the
principal to create a structure to frame that work? Improvement in teaching and thereby
students’ learning is created by building the capacity of teachers, school administrators,
and district administrators alike (Elmore, 2003; Fullan, Bertani, & Quinn, 2004; Loucks-
Horsley et al., 1998; Loucks-Horsley et al., 2010; Vasquez, 2008).

Another concern that surfaced during the study was distrust, distrust of the
district, of the school, and of other teachers, especially around professional development.
When explaining the surveys to teacher respondents, three of the four expressed concern
about honestly reporting the hours for professional development. It is, therefore, possible
that time for professional development activities were overstated. During another
conversation, fear of retribution was expressed for speaking frankly about a lack of
professional development support from the district and the condescending attitude of a
district science coach. The principal even seemed to hedge her responses about district
doing:

- And I can just say that we have not found our stride where we have in other
  content areas that are less stretched across buildings.

- I would like to see some different support from our teacher/district coach in
terms of helping to foster [content and pedagogical knowledge], but it just
  hasn’t gelled.
- I think some are just differently skilled than others.

In another conversation a teacher spoke of an atmosphere of distrust of each other within the building, with other teachers who taught science and those that did not. She described a cut throat atmosphere, of "waiting for trouble". Collaboration and substantive change need a culture of trust in order to do the hard work involved (Bryk & Schneider, 2003; Sergiovanni, 2005).

The district has focused its professional development attention exclusively on science note-booking for science instruction; and in fact, every classroom under observation used science notebooks every day, and the principal reported notebooks in use school wide. Teachers indicated on the RAND and CLES 2(20) surveys that they were more inquiry-oriented than was observed in classrooms. The closer the mean was to four the more student-centered or inquiry-based. As shown in Figure 14, only the learner gives priority to evidence in responding to questions was observed three-fourths of the time, with students directed to collect certain data, indicating that students were frequently engaged in hands-on investigations in which they had to collect data. The other areas of this framework were observed to be much less student-centered or inquiry-based. Either the other components were not present during the observation or they were at the lower end of the scale, closer to more teacher-directed than student-directed.

In one class students were working independently through a series of FOSS investigations, following the steps and procedures given them. The teacher was moving from group to group evaluating students’ lab write-ups, focusing on ensuring that all parts were present; a question, hypothesis with background knowledge, materials, procedures,
data, and conclusion. If these are all directed by the teacher, is it inquiry as described in the literature (Abrams, Southerland, & Evans, 2008; Bybee, 2006; Magnusson & Palincsar, 2005; National Research Council, 2000; O'Neill & Polman, 2004)? On the RAND survey this teacher responded that she would use inquiry-oriented student activities almost every day, indicating her belief that students were engaged in inquiry-instruction.

In another class the teacher used lab packets extensively to guide and direct students in hands-on activities. In some the expected outcome was given at the beginning of the packet and in most the testable question, a blank data table, and conclusion
questions were there for students to fill in. From these observations and others there seems to be a separation between what the literature describes as inquiry and teachers’ understanding of inquiry-based instruction. Increasing teachers’ experience with inquiry-based instruction should be a focus since numerous studies have reported gains in students’ science achievement, especially underserved students, with teachers who have participated in inquiry-based professional development (Banilower, 2002; Blanchard et al., 2009; Buczynski & Hansen, 2010; Kahle et al., 2000; Kanter & Konstantopoulos, 2010; Lee et al., 2008; Wenglinsky, 2000; Zozakiewicz & Rodriguez, 2007).

On the other hand teachers reported more hours of professional development devoted to strategies for teaching their traditionally underserved students, with two teachers reporting between 4-8 and two teachers reporting between 8-16 hours within the past year. The principal mentioned the school focus of being involved with a ‘No Place for Hate’ initiative, “that’s really to continue to develop that cultural sensitivity and cultural awareness”. The principal went on to explain,

we monitor our data carefully because what we were noticing, it was three years ago, this incredible skew in the number of African American males that were referred out of class and so we really paid attention to that and have been monitoring that and addressing that head on.

The other area teachers reported having more time with was the opportunity to collaborate with their teacher peers; this was not asked specific to science so it could have been interpreted as general grade level collaboration. Two teachers responded that they had between 4-8 hours this past year and two other teachers said they had more than 16 hours working with other teachers. The principal stated that teachers had grade level planning time, but that it was not specific to science. There is a culture of collaboration
that could be channeled into a focus on science pedagogy, inquiry-based instruction and a
clarification of the connection between state standards and the FOSS kits.

**Classroom Environment**

**Diversity of classes.**

School D was comprised of approximately 60% ethnic/racial minority and about
14% language minority students and those school demographics were reflected in each
classroom. In every classroom observed, students were randomly seated in groups around
the room, working together. The principal stated, “We are very deliberate in how we put
our classes together, so that we are not ending up with gender misbalanced classes or a
racial misbalanced class”. She does say, that because of the small size of the school, there
are students that are grouped together by ability which she explained is why she is so
deliberate with balancing the classes. Lee and Luylex (2007) caution that tracking can
create inequities for traditionally underserved students, but in the science classes
observed all students had the same learning targets and had the opportunity to achieve
high expectations (National Research Council, 1996).

While the district as a whole had 69% of its students qualifying for free/reduced
lunches; School D had significantly less with 29% eligible for federal lunch support. It’s
difficult through observation to identify students receiving free or reduced lunches, so it’s
assumed that each class was balanced for socio-economic factors. Almost fifty years ago
Coleman et al. (1966) found that the “social composition of the student body is more
highly related to achievement, independently of the students’ own social background,
than is any school factor” (p. 325). This was noted on the latest science PISA assessment
as well (PISA 2006: Science, 2007, p. 194). It would seem then that classes with approximately 70% of the students at a higher socio-economic level would provide the opportunity for all students to achieve at high levels.

**Inquiry-based instruction.**

The focus of this study was on the continuum of inquiry and what School D is doing to foster a minimal gap between groups in science achievement. Classroom observations were made to understand teachers’ practice and surveys were completed to ascertain teachers’ theoretical choices around inquiry-based instruction. Overall teachers indicated that they were, in theory, more likely to teach within an inquiry-oriented, constructivist framework. Figure 15 shows that teachers were more likely to indicate
inquiry-oriented choices for introductory activities and when responding to students’ differing explanations. Teachers, for the most part, were equally likely to choose inquiry-oriented teaching strategies as they were to choose other than inquiry-oriented strategies. Classroom 3’s teacher indicated that she was more likely to emphasize other than inquiry-oriented learning objectives. Classroom observations showed a practice of using a collection of hands-on investigations related to the content standards, but not necessarily student-centered, inquiry-focused. Using the Essential Features of Classroom Inquiry to focus observations, Figure 16 shows that all four of the teachers provided data tables or guidance in collecting data, indicating that all four science classes were very focus on engaging students in hands-on activities.

Four of the five components were more teacher-directed than student-directed, but in two classes students were given opportunities to formulate their own explanations. For
the most part, students were answering science questions even if those questions were primarily directed by the teacher or the materials, as in FOSS activities or lab packets. In five observations, less than half, students were given possible ways to use evidence to formulate a conclusion; more teacher-directed. During one observation students were asked to complete a claims and evidence chart, but the claim was given to them. In another class students were told that in the interest of time, they should skip completing the claims and evidence chart. Hand and his colleagues found that students who write claims and evidence are better able to create meaning from their data (Hand, Wallace, & Yang, 2004; Hand, Norton-Meier, Staker, & Bintz, 2009; Keys, Hand, Prain, & Collins, 1999).

Students were either given possible connections or were directed toward specific sources in half the observations. Students were primarily given the steps or procedures for communicating their learning, most frequently that was in the form of answering questions on a lab sheet instead of students forming a reasonable explanation on their own. On a continuum of inquiry the science teachers observed at School D were operating more at a level 1, structured inquiry where the questions and the data collection methods were given by the teacher, but interpretation was open to students (Blanchard et al., 2010). It would be a simple matter of opening data collection methods to students to move to level 2, guided-inquiry.

A key inquiry-based activity is to have students engage in extended, reiterative investigations. When asked how often do your students work on extended investigations or projects three of the four teachers rated this either 1, never, or 2, a few times a year.
The fourth teacher responded that her students would do this once or twice a week. What was not observed in any class was the cyclical, reiterative process described in the literature (Atkin & Karplus, 2002; Karplus, 2002; Magnusson & Palincsar, 2005; Yager, 1991). Two teachers started new lessons with hands-on exploration, but after the introduction students would engage in teacher-directed activities. One teacher had students investigating during every observation, but there was no opportunity for students to reflect and dive deeper into the topic, they simply moved on to next activity.

**Constructivist learning environment.**

Fraser and his colleagues found that the classroom environment strongly influenced student outcomes (Aldridge et al., 2000; Fraser, 2007; Taylor et al., 1997). Figure 17 shows the mean responses for each component of a constructivist classroom.
and how each teacher responded, showing that overall teachers rated critical voice as an area that is present frequently in their classes.

The scale of personal relevance was observed frequently in two of the four classes. Students were engaged with everyday objects looking for energy transformations. When they were figuring out how to use an equal arm balance, they were connecting to the real world. Students in Classroom 3 experienced uncertainty, the second CLES scale, when they were trying to measure the mass of air. This was the only example of uncertainty observed and teachers uniformly rated it an average of 3.25 of 5.

Although critical voice was not observed directly, it was evident that students felt safe and valued in their classes. They freely asked for help in answering questions and most students were actively involved in class discussions. Figure 17 shows that all teachers rated themselves at an average of 4 of higher; two teachers had an average of 5 of 5. On the RAND survey a set of questions asked how teachers would respond in a hypothetical class if students made a mistake. Three of the four were very unlikely to respond in a manner that would embarrass or call attention to students’ mistakes, substantiating the CLES rating. The CLES scale of shared control was most evident in Classroom 2; each class period ended with a class meeting, asking students to share how the learning went that day. In Classroom 3, students were given complete control during parts of each observation. Overall teachers rated themselves either 3.75 or 4 with the exception of the third grade teacher who rated her classroom at 2.5. The last CLES scale is student negotiation in which students are interacting and socially constructing meaning about science. This is an important strategy for teaching students learning English (Fradd,
Lee, Sutman, & Saxton, 2001; Hampton & Rodriguez, 2001; Lee, Buxton, Lewis, & LeRoy, 2006, Sutman, 1993). In every classroom during every observation students were engaged in conversations with other students, helping one another, teaching one another, and arguing with one another about science related topics.

**Summary**

**Instructional choices.**

In every class, third grade to eighth grade, the primary activity was hands-on investigations, to introduce or explore a topic of study, to further investigate a topic, and to learn about collecting and organizing data. Every student had and used a science notebook in every class that was observed. Teachers expected students to record not only their science investigations, but also their warm-ups and notes from either class discussions or from reading the textbook. Teachers used their own science notebooks to model organization and student responses. On a continuum of inquiry, classes were more structured, with teachers providing the testable question and method of data collection, but on the whole students were engaged with the question and the materials, collecting and analyzing data. Students were not working on mindless worksheets or answering questions from the textbook.

**Classroom environments.**

It was evident that students felt safe and valued in their classes. They freely asked for help in answering questions and most students were actively involved in class discussions. Teachers were mindful of choosing responses that would not put students on the spot and embarrass or belittle them. Student to student talk was the norm in every
class; helping one another, teaching each other, arguing and persuading others about their science understandings. This is a key component of teaching English and science to students learning English as a second language. Each classroom was rich with materials and tools for conducting investigations and one class had a mobile computer lab in her room that students had free access to.

**Interventions.**

Probably the most important intervention evident at School D is that students were intentionally placed in classes to ensure diversity. Because of the small size of the school, only two fifth, sixth, and eighth grade classes for example, tracking is difficult to avoid, but during classroom observations any differences in ability were not noticeable. It was the norm in every class for the teacher to move from student to student, group to group, checking in with students, answering questions, helping with difficulties and providing feedback on proficiency. One teacher was observed pulling students to her small group table for more support with the reading in content task.

**School practices.**

“Science classrooms should be racially shared spaces containing high-quality physical, material, and human resources” (Elmesky, 2006, p. 198). Every class was intentionally diverse, with students of all backgrounds collaborating to investigate scientific phenomena with a plethora of science equipment, tools, and supplies. Each class had a highly qualified science teacher, three of whom had master’s degrees and three of whom majored or minored in science. The school as a whole and thereby each class had an average socio-economic level higher than the district average. School D has
a principal focused on student achievement data, using them to focus planning and instruction and there is a culture of collaboration within grade levels.

**Challenges.**

One challenge noted during this exploratory case study was the gossamer connection between district science curriculum and the state content standards in science especially at the K-5 level. The district has chosen to use primarily FOSS kits as their K-5 curriculum and lists kit names for each grades’ expectations. It does not articulate the science content or process skills that students are to come away with at the end of each instructional year, so teachers are left figuring it out on their own and aiming at flimsy targets. If one aims straight at any target, it will be missed. But, if one aims above the target, then success the target is hit (Frankl, 2007). What’s needed is a set of coherent, specific, age-appropriate student learning goals that the district has identified as essential science content understandings aligned with state science standards, especially at the K-5 level.

Second, even though students at School D receive the same number of minutes as other students in the district, science instruction for students in fifth, seventh, and eighth grade is every other quarter instead of every other day like at the sixth grade level, possibly impacting the science CSAP scores at fifth and eighth grade. If science instruction every day is not possible within a schedule, it would seem that the next best plan would be every other day as is happening in the sixth grade.

Professional development both at the district level and at the school level is a third challenge area. What looks like a Laissez-Faire attitude on the part of the principal and
the district could be hiding the sense of not knowing what to do to improve science instruction. What is needed is a focus on building the capacity of all parties; district instructional leaders, district science coaches, principals, and science teachers at all grade levels. Through collaborative planning specific to science, teachers would be able to build a more complete understanding of the science learning expectations and would be able to focus instruction from the FOSS kits more directly at both content and process learning goals. This would also support teachers in building their confidence and providing some of the science background needed to teach the content. Given the disconnect in inquiry-based instruction between how teachers responded on the surveys compared to what was observed in classrooms, it would be vital to provide professional development in inquiry processes and inquiry-based science instruction advocated by the science community.

**Recommendations**

Recommendations from this study are three-fold. First, the school should consider alternating science and social studies instruction daily rather than quarterly to increase the continuity of science instruction and reduced the amount of re-teaching time necessary. Second, the district needs to create a set of coherent, specific, age-appropriate student learning goals that the district has identified as essential science content understandings and inquiry process skills tightly aligned with state science standards. FOSS kits are the tool not the curriculum. While waiting for this process at the district level, teachers should consider collaborative planning specific to science. The school has collaborative planning embedded in their culture, but can extend it to science. This would enable
teachers to build a more complete understanding of the science learning expectations from the state and they would be able to focus instruction from the FOSS kits more directly at both content and process learning goals.

Third, in addition to the professional development described above, a focus is needed on enhancing the leadership capacity of all parties, district administrators, principals, and teachers, involved in science instruction, science curriculum development, and science professional development. Increasing teachers’ experience with inquiry-based instruction should be a focus since numerous studies have reported gains in students’ science achievement, especially underserved students, with teachers who have participated in inquiry-based professional development.

Limitations

Even though the RAND survey and the CLES 2(20) were used in the past with thousands of teachers in order to validate the instruments, they have not been used in Colorado case study research with a very limited number of teachers, only four. Different results were possible given the small sample of teachers connected to the school site chosen. Prior to completing the RAND survey, three of the four teachers expressed concern that somebody would learn of their responses to professional development activities in the district and the school. This could have resulted in teachers overestimating the numbers of hours spent in particular professional development activities.

The CLES 2(20) was not administered to students in order to validate the teacher’s perceptions of their classroom compared to the perceptions of the students in
that class. A limitation with both surveys was that they were given as a paper pencil task not as an online or bubble sheet task, so respondents were able to choose more than one response which made it difficult to calculate averages. They were, though, able to make other comments that added to the researcher’s understanding of their thinking.

Interview and observation protocols were not piloted. Some questions on the principal interview seemed redundant and no questions were asked about the African American population in particular. A second interview was needed with the principal due to the fact that on the first interview specific questions about the science budget were not addressed. An additional constructivist observation tool would have been helpful as part of the observation protocol in focusing the researcher on constructivist oriented teaching and learning instead of relying on observation notes after the actual observation.

Classroom 4 was only observed two times during the data collection period while the other classes were observed three or four times, so it’s possible that the description of that class is not as complete as it could have been with more observations. The other classes were observed to the point of redundancy, but it’s likely this class was not.

Another limitation to this study was the fact that only one school was investigated, so comparative or additive dimensions could not be explored. However, as an exploratory case study, the picture created of School D can inform further research in inquiry-based instruction and its impact on traditionally underserved students. The value of this case study is iterated in Hamilton’s (2003) comments about switching the focus from large-scale reform efforts to small, grassroots reform, starting with one school and replicating what can be replicated from school to school.
**Recommendations for Further Research**

This study needs to be replicated with other cases of schools, also from the highest percentile and with higher percentages of traditionally underserved students in order to discover patterns in instructional choices, classroom environments, interventions and school practices.

An in-depth case study of the district level science support systems would inform this district and other districts like this one, what interventions and supports are needed to improve the system of science instruction at the district level and classroom science instruction system-wide.

Further investigations should be done with cases chosen from the lowest 25th percentile on the science CSAP/TCAP; predicting contrasting results to attempt at theoretical replication and to clearly identify the differences in instructional choices, classroom environments, interventions, and the school system between the lowest performing schools and the average performing schools with more traditionally underserved students.

Using the state ethnicity report and the report of free/reduced lunches, search for schools to study that have the highest percent of Hispanic students proficient or advanced. Another study could focus on African American students or on students eligible for free or reduced lunches.

Using state ethnicity and free/reduced lunch reports identify districts that have high percentages of traditionally underserved students performing at the proficient and
advanced level on the TCAP to discover how they have successfully met the needs of those students from the district level.

Development of a constructivist observation protocol based on Taylor, Fraser, and Fisher’s (1997) work could be another focus of further research. It would have been helpful in this study to have an observation protocol to collect and quantify observations of constructivist-based instruction to compare observed instructional choices and teacher reported preferences for constructivist instructional choices.

A disconnect was noted between the CLES scale of critical voice for students, students feeling safe and valued in their classrooms, and the reported distrust of their teachers for one another at the building level, but also an apparent unease between staff at the school and the district leadership. This would suggest a follow up study of the school and/or district to ascertain the affective environment and its relation to professional development.
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doi:10.1177/0895904806290126
Appendix A

Recruiting Email

Dear

My name is Lucinda Howe. I am a Ph.D. student majoring in Educational Administration and Policy Studies in the Morgridge College of Education at the University of Denver. I’m conducting a case study to fulfill the requirements for the degree of Doctor of Philosophy, looking at the school practices in a Colorado middle school that is performing at or above the 75th percentile on the eighth grade Science CSAP. Your school is also meeting the needs of your Latino students and students that are eligible for the free or reduced lunch program as evidenced by the percent of students in these populations at your school that are performing at or above the proficient level on the Science CSAP, higher than state averages and your district averages for these groups.

I would like to schedule a telephone meeting with you to discuss the possibility of coming into your school, meeting with you and the teachers that teach science in your school, conduct classroom observations, and do a school walk through.

I would greatly appreciate a reply to this email with your preferred date and a phone number to reach you. I’m available most days after 3 PM or on the weekends.

Thank you,

Lucinda Howe
Educational Administration and Policy Studies
University of Denver
Lucinda.Howe@du.edu
720-934-6112
Discussion checklist for initial phone call to describe the study in detail (note: this will be emailed to the Principal after the call if/when they agree for their school to be a participant)

1. Introduce self
2. Explain study
3. Explain how this school was picked
4. Answer any questions so far
5. Explain agenda for school visits
   a. Information pulled prior to or between school visits (45 minutes)
      i. Science budget information
         1. Science equipment (non-consumable items such as microscopes, scales, etc.)
         2. Consumable science supplies (materials that must be replenished such as chemicals, batteries, etc.)
         3. Science software (including applications, computer probes, etc.)
      ii. School schedule
      iii. Curriculum documents
         1. Pacing guides if any
         2. Benchmark assessments if any
   b. Tour of school (less than 60 minutes)
      i. Library/Media - resources for science
      ii. Hallways – pictures
      iii. Science classrooms – location
      iv. Science storage areas – resources
   c. Meet w/ and interview principal (45 – 60 minutes)
   d. Meet with science teachers (45 minutes)
      i. go over informed consent
      ii. confidentiality
      iii. Explain online survey program (30 – 45 minutes to complete)
      iv. Explain student surveys (less than 30 minutes to administer to students)
      v. Provide information and elicit volunteers for classroom observations
   e. Classroom Observations – 2 days
6. Schedule date and time for first school visit
7. Explore dates for classroom observations
8. Thank you
9. Send follow up email with this agenda
Appendix B

Informed Consent - Teachers
PRACTICES SUPPORTING STUDENT ACHIEVEMENT
IN SCIENCE

You are invited to participate in a research study conducted by Lucinda Howe, PhD candidate, from the Morgridge College of Education at the University of Denver. The purpose of this study is to explore what instructional choices, interventions, and school practices are in place in one middle school in Colorado with Hispanic students and students of poverty that are performing at or above the 75th percentile on the eighth grade Science CSAP. You were selected to participate in this study because you are currently a teacher or principal at this school.

The results of this study will be reported in Lucinda Howe’s doctoral dissertation. Lucinda Howe can be reached at 720-934-6112 or lucinda.howe@du.edu. This project is supervised by Dr. Kent Seidel, Morgridge College of Education, University of Denver, Denver, CO 80208, 303.871.2496, kent.seidel@du.edu.

Participation in this study should take about 45 minutes of your time to complete the teacher survey which has 51 questions for teachers about classroom instructional practices, classroom environment, resources allocated to science, professional development for science, and background information. Your principal will be involved in a 45 minute interview to ascertained resources, interventions, and professional development in the school. Participation in this project is strictly voluntary. The risks associated with this project are minimal. If, however, you experience discomfort you may discontinue the survey at any time. We respect your right to choose not to answer any questions that may make you feel uncomfortable. Refusal to participate or withdrawal from participation will involve no penalty or loss of benefits to which you are otherwise entitled. Completion of the survey will constitute consent to participate in this research project.

Your responses will be kept strictly confidential. The information collected about you and reported in the dissertation will be coded using randomly assigned numbers. Only the researcher will have access to your individual data and any reports generated as a result of this study will use only group averages and paraphrased wording.

Although no questions in this study address it, we are required by law to tell you that if information is revealed concerning suicide, homicide, or child abuse and neglect, it is required by law that this be reported to the proper authorities.

If you have any concerns or complaints about how you were treated during the study, please contact Susan Sadler, Chair, Institutional Review Board for the Protection of Human Subjects, at 303-871-3454, or Sylk Sotto-Santiago, Office of Research and
Directions for going online to complete the online survey are below:

I have read and understood the foregoing descriptions of the study called Practices Supporting Student Achievement in Science. I have asked for and received a satisfactory explanation of any language that I did not fully understand. I agree to participate in this study, and I understand that I may withdraw my consent at any time. I have received a copy of this consent form.

Signature ________________________________ Date ______________
Informed Consent – Teacher Classroom Observation
PRACTICES SUPPORTING STUDENT ACHIEVEMENT
IN SCIENCE

You are invited to participate in a research study conducted by Lucinda Howe, PhD candidate, from the Morgridge College of Education at the University of Denver. The purpose of this study is to explore what instructional choices, interventions, and school practices are in place in one middle school in Colorado with Hispanic students and students of poverty that are performing at or above the 75th percentile on the eighth grade Science CSAP. You were selected to participate in this study because you are currently a teacher at this school.

The results of this study will be reported in Lucinda Howe’s doctoral dissertation. Lucinda Howe can be reached at 720-934-6112 or lucinda.howe@du.edu. This project is supervised by Dr. Kent Seidel, Morgridge College of Education, University of Denver, Denver, CO 80208, 303.871.2496, kent.seidel@du.edu.

Participation in the classroom observation will involve you being observed teaching and interacting with your students, as well as observing student to student interactions during science instruction. This study was approved by the University of Denver's Institutional Review Board for the Protection of Human Subjects in Research on 04/12/2011.

Participation in the classroom observation is strictly voluntary. The risks associated with this project are minimal. If, however, you experience any discomfort you may ask the researcher to leave the class at any time. We respect your right to choose not to participate in the classroom observation. Refusal to participate or withdrawal from participation will involve no penalty or loss of benefits to which you are otherwise entitled.

The notes from this observation will be kept strictly confidential. The information collected about this class and reported in the dissertation will be coded using randomly assigned numbers. Only the researcher will have access to your individual data and any reports generated as a result of this study will use only group averages and paraphrased wording.

Although no questions in this study address it, we are required by law to tell you that if information is revealed concerning suicide, homicide, or child abuse and neglect, it is required by law that this be reported to the proper authorities.

If you have any concerns or complaints about how you were treated during the study, please contact Susan Sadler, Chair, Institutional Review Board for the Protection of Human Subjects, at 303-871-3454, or Sylk Sotto-Santiago, Office of Research and Sponsored Programs at 303-871-4052 or write to either at the University of Denver,
Office of Research and Sponsored Programs, 2199 S. University Blvd., Denver, CO 80208-2121.

You may keep this page for your records. Please sign the next page if you understand and agree to the above. If you do not understand any part of the above statement, please ask the researcher any questions you have.

I have read and understood the foregoing descriptions of the study called Practices Supporting Student Achievement in Science. I have asked for and received a satisfactory explanation of any language that I did not fully understand. I agree to participate in this study, and I understand that I may withdraw my consent at any time. I have received a copy of this consent form.

Signature ____________________________________ Date ______________
Informed Consent – Principal
PRACTICES SUPPORTING STUDENT ACHIEVEMENT IN SCIENCE

You are invited to participate in a research study conducted by Lucinda Howe, PhD candidate, from the Morgridge College of Education at the University of Denver. The purpose of this study is to explore what instructional choices, interventions, and school practices are in place in one middle school in Colorado with Hispanic students and students of poverty that are performing at or above the 75th percentile on the eighth grade Science CSAP. You were selected to participate in this study because you are currently a teacher or principal at this school.

The results of this study will be reported in Lucinda Howe’s doctoral dissertation. Lucinda Howe can be reached at 720-934-6112 or lucinda.howe@du.edu. This project is supervised by Dr. Kent Seidel, Morgridge College of Education, University of Denver, Denver, CO 80208, 303.871.2496, kent.seidel@du.edu.

Participation in this study should take about 45 minutes of your time for an interview to discuss resources, interventions, and professional development in the school as it pertains to science instruction. Participation in this project is strictly voluntary. The risks associated with this project are minimal. If, however, you experience discomfort you may discontinue the interview at any time. We respect your right to choose not to answer any questions that may make you feel uncomfortable. Refusal to participate or withdrawal from participation will involve no penalty or loss of benefits to which you are otherwise entitled. Completion of the interview will constitute consent to participate in this research project.

Your responses will be kept strictly confidential. The information collected about you and reported in the dissertation will be coded using randomly assigned numbers. Only the researcher will have access to your individual data and any reports generated as a result of this study will use only group averages and paraphrased wording.

Although no questions in this study address it, we are required by law to tell you that if information is revealed concerning suicide, homicide, or child abuse and neglect, it is required by law that this be reported to the proper authorities.

If you have any concerns or complaints about how you were treated during the study, please contact Susan Sadler, Chair, Institutional Review Board for the Protection of Human Subjects, at 303-871-3454, or Sylk Sotto-Santiago, Office of Research and Sponsored Programs at 303-871-4052 or write to either at the University of Denver, Office of Research and Sponsored Programs, 2199 S. University Blvd., Denver, CO 80208-2121.
You may keep this page for your records. Please sign the next page if you understand and agree to the above. If you do not understand any part of the above statement, please ask the researcher any questions you have.

I have read and understood the foregoing descriptions of the study called Practices Supporting Student Achievement in Science. I have asked for and received a satisfactory explanation of any language that I did not fully understand. I agree to participate in this study, and I understand that I may withdraw my consent at any time. I have received a copy of this consent form.

Signature _______________________________ Date ______________
Appendix C

Teacher Surveys

Adapted RAND Teacher Survey

Professional Development in Science

1. Teachers participate in many workshops, seminars, courses, and other organized professional development activities. These programs may address many areas of science, including pedagogy, content, and curriculum, but most programs have a particular focus. In the past 12 months, how much time have you spent on professional development activities that focused on the following aspects of teaching science? For activities or sessions that covered more than one topic, estimate the time for each topic covered.

<table>
<thead>
<tr>
<th>(Circle one response in each row)</th>
<th>None</th>
<th>Less than 4 hours</th>
<th>4 – 8 hours</th>
<th>9 – 16 hours</th>
<th>More than 16 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. In-depth study of science content</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>b. Methods of teaching science</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>c. Use of particular science curricula or curriculum materials</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>d. Students’ scientific thinking</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>e. Science standards or framework (NSES, NSTA, AAAS, state and / or district)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>f. Science assessment / testing</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>g. Use of educational technology for science instruction</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>h. Strategies for teaching diverse student populations</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>i. Opportunities for collaborating with peers, team teaching, or peer coaching</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
**Curriculum**

Think about a class that is typical in terms of the way you teach science, and select that class as the target class. If you teach a subject other than science, please think only of your typical science class.

2. In a typical week, how many hours of science instruction do students receive in the target class? 
   
   ________ hours per week

3. Please list the major science content areas that you have taught or will teach in the target class and how much time was or will be spent teaching each this school year.

<table>
<thead>
<tr>
<th>(Circle one response in each row)</th>
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<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Less than 1 week</td>
</tr>
<tr>
<td>__________________</td>
</tr>
<tr>
<td>a.</td>
</tr>
<tr>
<td>b.</td>
</tr>
<tr>
<td>c.</td>
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<tr>
<td>d.</td>
</tr>
<tr>
<td>e.</td>
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<td>f.</td>
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<tr>
<td>g.</td>
</tr>
<tr>
<td>h.</td>
</tr>
<tr>
<td>i.</td>
</tr>
</tbody>
</table>

4. Think about one of the major science content areas listed above. When you teach that unit to the target class, how much emphasis do you place on the following skills and activities?

<table>
<thead>
<tr>
<th>(Circle one response in each row)</th>
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<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>No emphasis</td>
</tr>
<tr>
<td>____________</td>
</tr>
<tr>
<td>a. <strong>Learning the useful and limiting</strong></td>
</tr>
</tbody>
</table>
attributes of models

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>b</td>
<td>Learning scientific vocabulary</td>
</tr>
<tr>
<td></td>
<td>1  2  3  4</td>
</tr>
<tr>
<td>c</td>
<td>Conducting a controlled investigation, manipulating one variable</td>
</tr>
<tr>
<td></td>
<td>1  2  3  4</td>
</tr>
<tr>
<td>d</td>
<td>Learning specific information about the content area</td>
</tr>
<tr>
<td></td>
<td>1  2  3  4</td>
</tr>
<tr>
<td>e</td>
<td>Collecting data</td>
</tr>
<tr>
<td></td>
<td>1  2  3  4</td>
</tr>
<tr>
<td>f</td>
<td>Learning about the contribution of science to everyday life</td>
</tr>
<tr>
<td></td>
<td>1  2  3  4</td>
</tr>
<tr>
<td>g</td>
<td>Constructing or drawing physical models to explain scientific phenomena</td>
</tr>
<tr>
<td></td>
<td>1  2  3  4</td>
</tr>
<tr>
<td>h</td>
<td>Identify independent and dependent variable in an investigation</td>
</tr>
<tr>
<td></td>
<td>1  2  3  4</td>
</tr>
<tr>
<td>i</td>
<td>Using evidence from an investigation to support a conclusion</td>
</tr>
<tr>
<td></td>
<td>1  2  3  4</td>
</tr>
<tr>
<td>j</td>
<td>Carrying out a planned experiment</td>
</tr>
<tr>
<td></td>
<td>1  2  3  4</td>
</tr>
<tr>
<td>k</td>
<td>Making observations and recording data</td>
</tr>
<tr>
<td></td>
<td>1  2  3  4</td>
</tr>
<tr>
<td>l</td>
<td>Predicting patterns and relationships</td>
</tr>
<tr>
<td></td>
<td>1  2  3  4</td>
</tr>
</tbody>
</table>

5. On average throughout the year, approximately how often do you employ the following teaching strategies in the target class?

<table>
<thead>
<tr>
<th></th>
<th>Never</th>
<th>A few times a year</th>
<th>Once or twice a month</th>
<th>Once or twice a week</th>
<th>Almost every day</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Lecture or introduce content through formal presentation</td>
<td>1  2  3  4  5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
b. Use open-ended questions

<table>
<thead>
<tr>
<th></th>
<th>Never</th>
<th>A few times a year</th>
<th>Once or twice a month</th>
<th>Once or twice a week</th>
<th>Almost every day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

c. Require students to supply evidence to support their claims

<table>
<thead>
<tr>
<th></th>
<th>Never</th>
<th>A few times a year</th>
<th>Once or twice a month</th>
<th>Once or twice a week</th>
<th>Almost every day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

d. Encourage students to explain concepts to one another

<table>
<thead>
<tr>
<th></th>
<th>Never</th>
<th>A few times a year</th>
<th>Once or twice a month</th>
<th>Once or twice a week</th>
<th>Almost every day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

e. Encourage students to consider alternative explanations

<table>
<thead>
<tr>
<th></th>
<th>Never</th>
<th>A few times a year</th>
<th>Once or twice a month</th>
<th>Once or twice a week</th>
<th>Almost every day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

f. Help students see connections between science and other disciplines

<table>
<thead>
<tr>
<th></th>
<th>Never</th>
<th>A few times a year</th>
<th>Once or twice a month</th>
<th>Once or twice a week</th>
<th>Almost every day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

6. On average throughout the year, approximately how often do your students take part in the following activities in the target class?

<table>
<thead>
<tr>
<th>Activity</th>
<th>Never</th>
<th>A few times a year</th>
<th>Once or twice a month</th>
<th>Once or twice a week</th>
<th>Almost every day</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Answer textbook/worksheet questions</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>b. Share ideas or solve problems with each other in small groups</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>c. Engage in hands-on science activities</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>d. Work of extended science investigations or projects (a week or more in duration)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>e. Learn science vocabulary</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>f. Record, represent, and/or analyze data</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>g. Take short-answer tests (e.g., multiple-choice, true/false, fill-n-the-</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
7. Are the following tools/materials available for use in the target class?

(Circle one response in each row)

<table>
<thead>
<tr>
<th>Tool/Item</th>
<th>Do Not Know</th>
<th>Not Available</th>
<th>Partially Available</th>
<th>Fully Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Weighing balances, spring scales</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>b. Beakers, graduated cylinders, test tubes</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>c. Thermometers</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>d. Metric rulers</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>e. Microscopes, magnifying lenses</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>f. Water for experiments</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>g. Chemical reagents (e.g., acids, bases)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>h. Rocks, sand, minerals</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>i. Stop watches</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>j. Probe ware (e.g., motion detectors, temperature, salinity)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Teaching Scenarios

Instructions. The following questions contain brief “scenarios” or stories that describe teaching situations and ask how you would respond in each case. There are many ways to teach science, and you may not organize your lessons in the manner that is presented. Please answer as if you were in the situation that is described. The scenarios are brief and do not describe every detail. Assume that other features are similar to your current school and your current students.

Please do the following:
a. Read the scenario.
b. Read the first possible option.
c. Circle the response that shows how likely you would be to do this option.
d. Read the next option and circle your response.
e. Repeat the process until you have responded to all the options.
f. Please evaluate each of the options independently of the other. In other words, you may select as many 1’s (or 2’s or 3’s or 4’s) as you like.

SCENARIO 1: SPRINGS (4 QUESTIONS)

Imagine you are teaching a unit on scientific variables to your target class, during which the students investigate the effects of variables in several different physical systems. You are starting a two-week series of lessons on springs. Students will be investigating how the period of a spring’s bounce is influenced by the mass placed at the end of the spring and the distance the spring is stretched before being released.

8. The first experimental activity in the series of lessons on springs involves an exploration of the effects of different masses at the end of the spring on the period of the spring’s bounce. There are different ways a teacher might begin this series of lessons.

How likely are you to do each of the following as an initial activity in this series of lessons?

<table>
<thead>
<tr>
<th>(Circle one response in each row)</th>
<th>Very unlikely</th>
<th>Somewhat unlikely</th>
<th>Somewhat likely</th>
<th>Very likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Have students read a short segment from a textbook, which describes a spring’s motion and the factors which affect its bounce</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>b. Ask students to share their ideas about how to design an investigation of the effects of different masses at the end of a spring</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>c. Give students different springs and masses to experiment with</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>d. Describe the relationship students will observe between the mass at the end of a spring and the period of its bounce</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>e. Demonstrate the procedures the</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
students should follow to complete the investigation

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>f. Ask students to give examples of how springs are used in their everyday lives</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>g. Define the word “variable” and ask students to identify variables in the spring investigation</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

9. Working in groups, students have begun to investigate the effect of the mass at the end of a spring on the period of its bounce. For each trial, they attach a different mass to the end of the spring. Then they stretch the spring the same specified distance each time and release it to begin bouncing. They measure the time it takes for the spring to complete 10 bounces. After taking their measurements, the pairs graph the time required for 10 bounces as a function of the mass on the end of the spring.

While walking around the classroom, you notice that one pair’s graph has a jagged appearance. You discover that the two students decided to alternate controlling the stopwatch and counting the bounces, but they used different criteria for counting the bounces. When it was his turn, Ahmed counted, each complete cycle – from the spring’s highest point, to its lowest point, and back again – as one bounce. Justin counted each change of direction – from highest point to the lowest point OR from the lowest point to the highest point – as a separate bounce.

How likely are you to respond to Ahmed and Justin in each of the following ways?

(Circle one response in each row)

<table>
<thead>
<tr>
<th></th>
<th>Very unlikely</th>
<th>Somewhat unlikely</th>
<th>Somewhat likely</th>
<th>Very likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Review with the entire class the procedures they were supposed to use, including how to define one bounce; demonstrate how to count correctly</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>b. Ask students to count the number of bounces simultaneously and compare their results</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>c. Remind students that they need to use the same criteria for counting bounces</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>d. Point out that they are using different</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
criteria for counting the bounces and ask if they think it matters

e. Ask each student what he found about the mass at the end of the spring and the number of bounces, and then ask whether their combined graph shoes this finding

f. Ask students to label each point of their graph with the name of the student who did the counting for that point, then help them look for a pattern in the results

10. In a second set of investigations, groups of students use the same mass at the end of the spring and vary the distance that the spring is stretched before being released. Students graph the time required for 10 bounces as a function of the distance the spring is stretched before being released. They are surprised to notice that their graphs are flat lines, indicating that the distance stretched doesn’t affect the period of the bounce.

During a class discussion, students struggle to explain the unexpected result. Deborah points out that the spring has to go further to complete one period when it is stretched further, so it should take longer the more it is stretched. Christina expected the opposite result because the spring snaps back more quickly the further she stretches it. Since it moves so fast, she says it should take a shorter time.

As the teacher, you know that the further the spring is stretched, the faster it travels during its bounce. This exactly balances the extra distance that the spring travels.

How likely are you to respond to these comments in each of the following ways?

<table>
<thead>
<tr>
<th>(Circle one response in each row)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very unlikely</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>a. Indicate that these are both interesting observations and continue with the lesson</td>
</tr>
<tr>
<td>b. Tell students that the two factors balance out, so that the distance the spring is stretched doesn’t actually affect the period</td>
</tr>
<tr>
<td>c. Have students discuss the result in</td>
</tr>
</tbody>
</table>
groups to see if they can resolve the apparent discrepancy and answer the question of why the distance stretched doesn’t affect the period of the spring’s bounce

d. Show students the formula for the period of a spring’s bounce, in which mass, but not distance stretched, affects the period

e. Ask students to consider the simpler case of two students whose trips to school take the same amount of time: one who lives 2 blocks away and walks to school, and another who lives 2 miles away and takes the bus

f. Have students write about whether they think it makes sense that the period of the spring’s bounce does not depend on how far the spring is stretched

11. If you were to teach a series of lessons on springs to your current class, how much emphasis would you place on each of the following learning objectives?

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>No emphasis</th>
<th>Slight emphasis</th>
<th>Moderate emphasis</th>
<th>Great emphasis</th>
</tr>
</thead>
</table>
a. Students will be able to list the factors that do and do not affect the period of a spring’s bounce | 1           | 2              | 3                 | 4              |
b. Students will understand the relationships between different factors and the period of a spring’s bounce | 1           | 2              | 3                 | 4              |
c. Students will learn to follow instructions to complete an investigation         | 1           | 2              | 3                 | 4              |
d. Students will recognize the importance of keeping conditions the same when conducting an investigation | 1           | 2              | 3                 | 4              |
e. Students will recognize the importance of observing and recording accurately

f. Students will be able to design their own experiments like this one, i.e., to investigate the influence of conditions on physical systems, such as pendulums

g. Students will be able to create a graph that displays data from an experiment

SCENARIO 2: HEREDITY AND PUNNETT SQUARES (4 QUESTIONS)

Instructions. Please imagine that you are in the situation that is described, and indicate how likely or unlikely you would be to do each of the possible options. We understand that you may not actually organize your lessons in the manner that is presented here, but try to respond as if you were in the situation.

Read each option and circle the number that shows how likely you would be to do that option. Remember, you may select as many 1’s (or 2’s or 3’s or 4’s) as you like.

Imagine you are teaching a seven-week unit on heredity to an eighth-grade science class. You have just completed a series of lessons in which students learned about the role of dominant and recessive genes in determining the traits of an organism. You are about to begin a week-long series of lessons in which students learn to use Punnett squares (See Figure 1) to investigate the possible gene combinations from genetic crosses. Students will identify all the possible genetic combinations resulting from the breeding of successive generations of African bees (that possess two dominant genes for aggressiveness), European bees (that possess two recessive genes for non-aggressiveness) and their offspring.

Cross between pure dominant (AA) and pure recessive (aa)

\[
\begin{array}{cc}
A & A \\
 a & Aa & Aa \\
a & Aa & Aa \\
\end{array}
\]

Figure 1. Example of Punnett square

12. You are now ready to begin your lessons on genetic crosses. There are different ways a teacher might begin this series of lessons.
How likely are you to do each of the following as an initial activity in this series of lessons? (Circle one response in each row)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Very unlikely</th>
<th>Somewhat unlikely</th>
<th>Somewhat likely</th>
<th>Very likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Explain the procedure for using Punnett squares</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>b. Have students view a video that describes how inherited traits are passed on to offspring</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>c. Review what the students have learned about dominant and recessive genes</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>d. Have students read an article about importing African bees into the Western Hemisphere and discuss what might happen as the bees interbreed with native European bees</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>e. Show students pictures of families with varying eye colors and ear lobes, and have the students discuss the features that are retained from parent to offspring</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>f. Ask students to predict all of the possible outcomes from crossing a pure and a hybrid bee and explain how they determined these outcomes</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

13. Students have been introduced to the use of Punnett squares, and now they will identify the possible outcomes of a genetic cross between pure African bees and pure European bees. Students have read that pure African bees have two dominant, aggressive genes (AA) while pure European bees have two recessive, non-aggressive genes (aa). You ask students to describe the behavioral traits of the offspring that might result from this cross.

One student, Samuel, explains that the offspring will be less aggressive than the African bees because they will have more genes for non-aggressive behavior than pure African bees.
As the teacher, you know that because the aggressive gene is dominant, all the offspring with either one or two dominant genes will have the trait (aggressiveness).

How likely are you to respond to Samuel’s answer in each of the following ways?

<table>
<thead>
<tr>
<th>(Circle one response in each row)</th>
<th>Very unlikely</th>
<th>Somewhat unlikely</th>
<th>Somewhat likely</th>
<th>Very likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Remind the student that the gene for aggressive behavior is dominant, so the bees will be aggressive</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>b. Ask the students whether they agree with Samuel’s hypothesis and why</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>c. Acknowledge that the student is correct about the presence of a non-aggressive gene, but ask him about the influence of the other gene</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>d. Ask the class to review how pure and hybrid gene combinations affect the features of bees</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>e. Draw Samuel’s Punnett square on the board, and ask the class how to identify the aggressive offspring</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>f. Explain that in some cases both the dominant and recessive genes are expressed, but in this case the traits are determined solely by the presence of the dominant gene</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

14. Next, students are asked to use what they have learned about genetics to predict how the behavior of bees in America will change after the European bees (aa) currently living here breed with African bees (AA) that have been introduced. You ask students to work in groups of 3-4 students to predict whether all bees in America would eventually become aggressive.

One group explains that eventually all the bees in America will become aggressive because when you cross a pure African bee with a pure European bee, all the offspring are aggressive.
Another group disagrees, saying that two hybrid (Aa) bees may cross-breed, and some of the offspring will have only the non-aggressive gene (aa) and they will continue to be non-aggressive.

How likely are you to respond to these comments in each of the following ways?

<table>
<thead>
<tr>
<th>(Circle one response in each row)</th>
<th>Very unlikely</th>
<th>Somewhat unlikely</th>
<th>Somewhat likely</th>
<th>Very likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Explain that the second group is correct because over time hybrids will mate with hybrids</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>b. Draw a Punnett square for the cross of two hybrid bees (Aa) and fill in all the outcomes to show the genes of all the offspring</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>c. Have the two groups show how they used Punnett squares to reach their conclusions</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>d. Ask the other groups which explanation they agree with and why</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>e. Ask the first group what the Punnett square of the next generation of offspring will look like</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

15. If you were to design a series of lessons on genetics and Punnett squares for the target class using one or more species as examples, how much emphasis would you place on each of the following learning objectives?

<table>
<thead>
<tr>
<th>(Circle one response in each row)</th>
<th>No emphasis</th>
<th>Slight emphasis</th>
<th>Moderate emphasis</th>
<th>Great emphasis</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Students will be able to define the terms gene, offspring, pure, and hybrid</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>b. Students will learn how to use Punnett squares to show all the possible outcomes of a genetic cross</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
c. Students will learn to appreciate the importance of genetics for understanding changes in organisms around the world

d. Students will be able to explain the inheritance of traits in the particular species studied (e.g., bees)

e. Students will understand the impact of the spread of foreign species on native plants and animals

f. Students will understand the interplay between environmental and genetic factors in our evolving world (e.g., adaptation, natural selection)

g. Students will become aware of the genetic diversity among species

Teacher Background
16. What grade are you teaching this year? Grade

17. Are you: Male

Female


b. American Indian or Alaskan Native

c. Asian or Pacific Islander

d. Hispanic

e. White (not of Hispanic origin)

f. Other (describe)

19. What is the highest degree you hold?
20. Did you **major** in science or a science-intensive field (e.g., pre-med, engineering) for your Bachelor’s degree?
   - No 1
   - Yes 2

21. Did you **minor** in science or a science-intensive field (e.g., pre-med, engineering) for your Bachelor’s degree?
   - No 1
   - Yes 2

22. What type of teaching certification do you hold?
   a. Not certified 1
   b. Temporary, provisional, or emergency certification (requires additional coursework before regular certification can be obtained) 2
   c. Probationary certification (the initial certification issued after satisfying all requirements except the completion of a probationary period) 3
   d. Regular or standard certification 4

23. Do you hold a specific certificate or endorsement for teaching science?
   - No 1
   - Yes 2

24. Including this year, how many years have you taught on a full-time basis?  
   - Years

214
25. Including this year, how many years have you taught science?  
   Years

26. Including this year, how many years have you taught this grade level?  
   Years

27. Have you ever served as a lead teacher in science?  
   No  
   Yes

28. With respect to the science that you are asked to teach, how confident are you in your knowledge of science?  
   a. Not confident at all  
   b. Somewhat confident  
   c. Moderately confident  
   d. Very confident

29. What percent of students in target class is classified as Limited English (LEP) or English Language Learners (ELL)?  
   ______%  

30. How would you describe the target class in terms of variation in student science ability?  
   a. Fairly homogenous and low in ability  
   b. Fairly homogenous and average in ability  
   c. Fairly homogenous and high in ability  
   d. Heterogeneous with a mixture of two or more ability levels
Constructivist Learning Environment Survey CLES 2(20)

What Happens in My Classroom – Teacher Form

<table>
<thead>
<tr>
<th>In this class . . . .</th>
<th>Almost Never</th>
<th>Seldom</th>
<th>Sometimes</th>
<th>Often</th>
<th>Almost Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning about the World</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31. Students learn about the world inside and outside of school.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>32. New learning relates to experiences or questions about the world inside and outside of school.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>33. Students learn how science is a part of their inside-and-outside-of-school lives.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>34. Students learn interesting things about the world inside and outside of school.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Learning about Science</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35. Students learn that science cannot always provide answers to problems.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>36. Students learn that scientific explanations have changed over time.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>37. Students learn that science is influenced by people’s cultural values and opinions.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>38. Students learn that science is a way to raise questions and seek answers.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Learning to Speak Out</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39. Students feel safe questioning what or how they are being taught.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>40. I feel students learn better when they are allowed to question what or how they are being taught.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>41. It’s acceptable for students to ask for clarification about activities that are confusing.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>42. It’s acceptable for students to express concern about anything that gets in the way of their learning.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
Learning to Learn

43. Students help me plan what they are going to learn.

44. Students help me to decide how well they are learning.

45. Students help me to decide which activities work best for them.

46. Students let me know if they need more/less time to complete an activity.

Learning to Communicate

47. Students talk with other students about how to solve problems.

48. Students explain their ideas to other students.

49. Students ask other students to explain their ideas.

50. Students are asked by other to explain their ideas.

51. To what would you attribute your school’s achievement levels for different subgroups of children? Please describe.

Thank you very much for completing this survey. The hope is that information from this study will help guide teachers of science in Colorado.
Appendix D

Principal Interview Questionnaire

General

1. To what would you attribute your school’s achievement levels for your Hispanic students and students receiving free/reduced lunches?

Resources

2. How do you find ways to make more effective use of time currently available within the school calendar?

3. How do you insure that diverse groups are proportionately represented in higher level math and science courses?

4. What specific support if any do you receive from the district for science instruction?

Interventions

5. What interventions might a student receive if they were performing below proficient in science?

6. What interventions might a student receive if they were performing below proficient in other areas, literacy and math?

Professional Development

7. Would you say you have teacher leaders within your school in the science content area?

8. How are science teacher leaders, either within the school or district, utilized for professional development?

9. Are your science teachers provided with sufficient time and opportunities to work together to improve their content knowledge and pedagogy for teaching and students’ learning?

10. How does professional development in your building address teaching diverse students?
11. What opportunity do science teachers have to collaborate with language acquisition teachers?

12. How are disaggregated data of subgroups shared with the school community? What, then, are your next steps?

Background

13. How many years have you been a principal?

14. How many years have you been the principal at this school?

15. How familiar are you with the 2009 Colorado Academic Standards for Science?
Follow-up Principal Interview Questionnaire:

Science budget information:

1. Science equipment (non-consumable items such as microscopes, scales, etc.)

2. Consumable science supplies (materials that must be replenished such as chemicals, batteries, etc.)

3. Science software (including applications, computer probes, etc.)

4. Science topic books for the media center

What was unique about the 8th grade in 2009?

When did the boundaries for the school change? And how did that affect the demographics of the school?

Data book: CSAP content disaggregation:
### Follow-up Teacher Interview Questionnaire

<table>
<thead>
<tr>
<th></th>
<th>2009 and before</th>
<th>After 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>As a teacher leader, how did you work with a district coach?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>As a classroom teacher, how has your instructional day changed?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What, if anything, do think was unique about the 8th graders in 2009?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What else may have been different?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix E

Analysis Protocol for Curriculum Documents

District Name:

School Name:

<table>
<thead>
<tr>
<th>Major Science Topics Taught in Each Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kindergarten</td>
</tr>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; Grade</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; Grade</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; Grade</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt; Grade</td>
</tr>
<tr>
<td>5&lt;sup&gt;th&lt;/sup&gt; Grade</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Major Science Topics Taught</th>
<th>6&lt;sup&gt;th&lt;/sup&gt; Grade</th>
<th>7&lt;sup&gt;th&lt;/sup&gt; Grade</th>
<th>8th Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; Quarter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; Quarter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; Quarter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt; Quarter</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Analysis Protocol for Curriculum Documents

**District Name:** District 4  
**School Name:** School D

<table>
<thead>
<tr>
<th>Kindergarten</th>
<th>1st Grade</th>
<th>2nd Grade</th>
<th>3rd Grade</th>
<th>4th Grade</th>
<th>5th Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animals 2 by 2; Balls and Ramps*; Wood and Paper</td>
<td>Insects; Solids and Liquids; Pebbles, Sand, and Silt</td>
<td>New Plants; Balance and Motion; Air and Weather</td>
<td>Structures of Life; Aviation*; Water</td>
<td>You and Your Body*; Magnetism and Electricity; Sun, Earth, and Moon*</td>
<td>Environments; Mixtures and Solutions; Variables; Landforms</td>
</tr>
</tbody>
</table>

*Not a FOSS kit

<table>
<thead>
<tr>
<th>Major Science Topics Taught</th>
<th>6th Grade</th>
<th>7th Grade</th>
<th>8th Grade</th>
</tr>
</thead>
</table>
| **1st Quarter**             | Minerals  
Rocks  
Soils | Cells  
Genetics | Mass v. Weight  
States of Matter  
Physical Properties of  
Matter  
Atoms, Elements,  
Molecules, and  
Compounds  
Mixtures and  
Compounds |
| **2nd Quarter**             | Plate Tectonics  
Earthquakes,  
Mountains, and  
Volcanoes  
Geologic Time  
Natural Resources | Classification  
Structure and  
Function in Living  
Things | Physical and Chemical  
changes  
Conservation of Mass  
Linear Motion  
Forces and Motion  
Forms of Energy |
| **3rd Quarter**             | Earth’s Waters  
Weather | Human Body  
Systems | Conservation of Energy  
Energy Transformations  
Light  
Electricity |
| **4th Quarter**             | Space | Ecology | Electricity  
Sound Waves  
Magnetism and  
Electricity  
Alternative Energy |
## Appendix F

### School Observation Protocol

**District:**

**School:**

**Student Demographics:**

<table>
<thead>
<tr>
<th></th>
<th>Number of Students</th>
<th>Percent of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>School Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic students</td>
<td></td>
<td></td>
</tr>
<tr>
<td>African American students</td>
<td></td>
<td></td>
</tr>
<tr>
<td>American Indian students</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qualify for Free Lunch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qualify for Reduced Lunch</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Teachers:**

<table>
<thead>
<tr>
<th></th>
<th>Number of science teachers (middle level)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6\textsuperscript{th} grade</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Number of teachers teaching science (elementary level)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary science specialists</td>
<td></td>
</tr>
</tbody>
</table>

**Schedule:**

- Number of hours of science instruction per day
- Number of hours of science instruction per week
Intervention classes:

Types of intervention classes

Typical Number of Hours per day per student

Number of Hours of science intervention per day

Typical number of Hours per week per student

Number of Hours of science intervention per week
School Observation Protocol

District: 4

School: D

Student Demographics:

<table>
<thead>
<tr>
<th></th>
<th>Number of Students</th>
<th>Percent of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>School Total</td>
<td>628</td>
<td></td>
</tr>
<tr>
<td>Hispanic students</td>
<td>161</td>
<td>25.6%</td>
</tr>
<tr>
<td>African American students</td>
<td>112</td>
<td>17.8%</td>
</tr>
<tr>
<td>American Indian students</td>
<td>4</td>
<td>0.6%</td>
</tr>
<tr>
<td>Qualify for Free/ Reduced Lunch</td>
<td>184</td>
<td>29.3%</td>
</tr>
<tr>
<td>Limited English Students</td>
<td>93</td>
<td>14.8%</td>
</tr>
</tbody>
</table>

Teachers:

<table>
<thead>
<tr>
<th></th>
<th>Number of science teachers (middle level)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6th grade</td>
</tr>
<tr>
<td>1 teacher taught two sections of science on alternate days</td>
<td>1 teacher taught two sections of 7th grade 2nd and 4th quarters and two sections of 8th grade 1st and 3rd quarter</td>
</tr>
</tbody>
</table>

Number of teachers teaching science (elementary level): 5th grade was considered middle level with 1 teacher teaching 3 sections of science 1st and 3rd quarter and the same teacher teaching 3 sections of social studies 2nd and 4th quarters

A 3rd grade class was also observed.

Elementary science specialists – The 7th/8th grade science teacher was the school’s science teacher leader

Schedule:

Number of hours of science instruction per day

5th – 8th grade students have science 105 minutes per day for half the year, averaging 55 minutes per day for the year. When students aren’t in science they are in Social Studies.

Number of hours of science instruction per week

5th – 8th grade students average 4 hours and 35 minutes per week of science instruction for the year.
Intervention classes:

Types of intervention classes
   English Language Development classes

Typical Number of Hours per day per student

Number of Hours of science intervention per day
None outside of regular instruction

Science preparation room:
FOSS kits – approximately 15 different kits covering physical, life, and earth for different grade levels
STC kits – approximately 13 different kits covering physical, life and earth for different grade levels
Other kits – Animals, Wood and Paper, You and Your Body, and a Delta kit of Weather Tools
Household chemicals and food items
Chemicals with classification stickers
Models of organs and a skeleton
Various Venier probes to collect data digitally
Glassware – test tubes, beakers

Second of two science classrooms
Available for classes to use for science units
Outfitted with
   Sinks, electric outlets, lab tables and stools, a demonstration table, plant trays and lighting system for the Plant Growth and Development STC kit
More cabinet space for storing more equipment

Hallways
Every hallway had student, kindergarten through sixth grade, work hanging up showing what proficient looked like on a particular assignment; there was reading, writing, math, and the art hallway was a plethora of art works both 2-D and 3-D of all grade levels
No science specific work was posted on hallway walls

Media center
Staffed by a parent volunteer
Science nonfiction was in one aisle with two of the three shelves partially filled with books
In one corner was a brightly colored and decorated area specifically designed by and for the older students

PBiS
One of the district’s Positive Behavior and interventions School (PBiS)
Supportive
Overcome
Accountable
Respectful
Appendix G

Classroom Observation Protocol

Teacher:

Grade:

Number of Students:

Science Content Focus:

General Description of Classroom Activity:

Essential Features of Classroom Inquiry and Their Variations

<table>
<thead>
<tr>
<th>Essential Feature</th>
<th>Variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Learner engages in scientifically oriented questions</td>
<td>Learner poses a question</td>
</tr>
<tr>
<td>2. Learner gives priority to evidence in responding to questions</td>
<td>Learner determines what constitutes evidence and collects it</td>
</tr>
<tr>
<td>3. Learner formulates explanations from evidence</td>
<td>Learner formulates explanations after summarizing</td>
</tr>
<tr>
<td>Evidence</td>
<td>Evidence</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>4. Learner connects explanations to scientific knowledge</td>
<td>Learner independently examines other resources and forms the links to explanations</td>
</tr>
<tr>
<td>Learner directed toward areas and sources of scientific knowledge</td>
<td>Learner given possible connections</td>
</tr>
<tr>
<td>5. Learner communicates and justifies explanations</td>
<td>Learner forms reasonable and logical argument to communicate explanations</td>
</tr>
<tr>
<td>Learner coached in development of communication</td>
<td>Learner provided broad guidelines to use and sharpen communication</td>
</tr>
<tr>
<td>Learner given steps and procedures for communication</td>
<td>Learner given steps and procedures for communication</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>More</th>
<th>Amount of Learner Self-Direction</th>
<th>Less</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less</td>
<td>Amount of Direction from Teacher or Material</td>
<td>More</td>
</tr>
</tbody>
</table>

(National Research Council, 2000)