THE STUDENT PERSPECTIVE
OF HIGH SCHOOL LABORATORY EXPERIENCES

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High school science laboratory experiences are an accepted teaching practice across the nation despite a lack of research evidence to support them. The purpose of this study was to examine the perspective of students—stakeholders often ignored—on these experiences. Insight into the students’ perspective was explored progressively using a grounded theory methodology. Field observations of science classrooms led to an open-ended survey of high school science students, garnering 665 responses. Twelve student interviews then focused on the data and questions evolving from the survey.

The student perspective on laboratory experiences revealed varied information based on individual experience. Concurrent analysis of the data revealed that although most students like (348/665) or sometimes like (270/665) these experiences, some consistent factors yielded negative experiences and prompted suggestions for improvement. The category of responses that emerged as the core idea focused on
student understanding of the experience. Students desire to understand the why do, the how to, and the what it means of laboratory experiences. Lacking any one of these, the experience loses educational value for them. This single recurring theme crossed the boundaries of age, level in school, gender, and even the student view of lab experiences as positive or negative.

This study suggests reflection on the current laboratory activities in which science teachers engage their students. Is the activity appropriate (as opposed to being merely a favorite), does it encourage learning, does it fit, does it operate at the appropriate level of inquiry, and finally what can science teachers do to integrate these activities into the classroom curriculum more effectively? Simply stated, what can teachers do so that students understand what to do, what’s the point, and how that point fits into what they are learning outside the laboratory?
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TABLE OF CONTENTS

ACKNOWLEDGMENTS ........................................................................................................ iii

LIST OF FIGURES ........................................................................................................... vii

LIST OF TABLES ............................................................................................................. viii

CHAPTER
I INTRODUCTION ........................................................................................................ 1
  Background ............................................................................................................... 1
  Statement of the Problem ...................................................................................... 2
  Purpose of the Study ............................................................................................. 7
  Research Question ................................................................................................. 10
  Definitions .............................................................................................................. 10
  Researcher Assumptions ....................................................................................... 11
  Organization of the Study ....................................................................................... 12

II LITERATURE REVIEW .......................................................................................... 14
  Overview .............................................................................................................. 14
  Early Research on Laboratory Effectiveness .................................................... 14
  Current Research on Laboratory Effectiveness ................................................. 17
  Closing the Methodological Gap: A Grounded Theory Review ......................... 22
  The Possibility of a Converged Grounded Theory ............................................. 28

III RESEARCH DESIGN ............................................................................................ 30
  Introduction .......................................................................................................... 30
  Study Overview ................................................................................................... 30
  Participants ......................................................................................................... 32
  Sampling Procedure ............................................................................................. 33
  Data Collection .................................................................................................... 34
  Data Analysis in Grounded Theory Methodology ................................................. 38
  Rigor .................................................................................................................... 43
  Limitations of the Study ....................................................................................... 45

IV CONCURRENT DATA COLLECTION AND ANALYSIS ................................ 48
  Introduction .......................................................................................................... 48
  The Open-Ended Student Survey ........................................................................ 50
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Data Summary</td>
<td>49</td>
</tr>
<tr>
<td>2.</td>
<td>Favorite activity</td>
<td>54</td>
</tr>
<tr>
<td>3.</td>
<td>Least favorite activity</td>
<td>55</td>
</tr>
<tr>
<td>4.</td>
<td>Lab as least favorite activity</td>
<td>56</td>
</tr>
<tr>
<td>5.</td>
<td>Why do teachers make you do labs?</td>
<td>59</td>
</tr>
<tr>
<td>6.</td>
<td>What students liked about labs</td>
<td>80</td>
</tr>
<tr>
<td>7.</td>
<td>What students disliked about labs</td>
<td>81</td>
</tr>
<tr>
<td>8.</td>
<td>Student suggestions for improvement</td>
<td>82</td>
</tr>
<tr>
<td>9.</td>
<td>Categorization of what students who liked labs liked about them</td>
<td>129</td>
</tr>
<tr>
<td>10.</td>
<td>Categorization of what students who liked labs disliked about them</td>
<td>130</td>
</tr>
<tr>
<td>11.</td>
<td>Categorization of what students who liked labs suggest to improve them</td>
<td>131</td>
</tr>
<tr>
<td>12.</td>
<td>Categorization of what students who disliked labs liked about them</td>
<td>132</td>
</tr>
<tr>
<td>13.</td>
<td>Categorization of what students who disliked labs disliked about them</td>
<td>133</td>
</tr>
<tr>
<td>14.</td>
<td>Categorization of what students who disliked labs suggest</td>
<td>134</td>
</tr>
<tr>
<td></td>
<td>to improve them</td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>Categorization of what students who sometimes liked labs liked</td>
<td>135</td>
</tr>
<tr>
<td></td>
<td>about them</td>
<td></td>
</tr>
<tr>
<td>16.</td>
<td>Categorization of what students who sometimes liked labs disliked</td>
<td>136</td>
</tr>
<tr>
<td></td>
<td>about them</td>
<td></td>
</tr>
<tr>
<td>17.</td>
<td>Categorization of what students who sometimes liked labs suggest</td>
<td></td>
</tr>
</tbody>
</table>
to improve them .................................................................................................................137
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Coding of Responses: Why Those Who Liked Labs Liked Them</td>
<td>62</td>
</tr>
<tr>
<td>3. Coding of Responses: Suggestions to Improve Labs Among Those</td>
<td></td>
</tr>
<tr>
<td>Who Liked Them</td>
<td>63</td>
</tr>
<tr>
<td>4. Coding of Responses: Why Those Who Disliked Labs Disliked Them</td>
<td>64</td>
</tr>
<tr>
<td>6. Coding of Responses: Suggestions to Improve Labs Among Those</td>
<td></td>
</tr>
<tr>
<td>Who Disliked Them</td>
<td>65</td>
</tr>
<tr>
<td>7. Coding of Responses: Why Those Who Sometimes Liked Labs Liked Them</td>
<td>66</td>
</tr>
<tr>
<td>8. Coding of Responses: What Those Who Sometimes Liked Labs Disliked</td>
<td></td>
</tr>
<tr>
<td>About Them</td>
<td>67</td>
</tr>
<tr>
<td>9. Coding of Responses: Suggestions to Improve Labs Among Those</td>
<td></td>
</tr>
<tr>
<td>Who Sometimes Liked Them</td>
<td>68</td>
</tr>
<tr>
<td>10. Coding of Responses: Why Students Liked Labs</td>
<td>69</td>
</tr>
<tr>
<td>11. Coding of Responses: What Students Disliked about Labs</td>
<td>70</td>
</tr>
<tr>
<td>12. Coding of Responses: Suggestions to Improve Labs by All Students</td>
<td>71</td>
</tr>
</tbody>
</table>
CHAPTER 1
INTRODUCTION

Background

On the cover of the February 13, 2006, issue of *Time* magazine, its editors posed the following question: “Is America flunking science?” When the problem of science education reaches the mainstream press, those in the profession should take note. In a particularly distressing comparison in the cover story, Lemonick (2006) compared the state of affairs in science education at the opening of the 21st century to the era preceding the *Sputnik* launch saying, “the quality of education in math and science in elementary and high schools has plummeted” (p. 24). Unfortunately, the author was not alone in this assessment.

Lemonick’s article was in part a response to the 2006 State of the Union address given by President George W. Bush, in which he outlined the America Competitiveness Initiative, a policy aimed at keeping the USA at the forefront of the world through math, science, and technology. Major components of this initiative focused on the improvement of math and science education, including professional development for science teachers, recruitment of highly qualified science teachers, an emphasis on advanced science courses, and the development of research-based curricula (Domestic Policy Council, 2006). Calls for a “scientifically, technically, and numerically literate population” and “rigorous courses that teach important analytical, technical, and problem-solving skills” (Domestic Policy Council, p. 15) served as the backdrop for this study.
Providing the best science education for American youth is a goal not only of policymakers but also science educators, who have a fixed amount of time to implement teaching methods with which they are comfortable. Given the pressure placed on these teachers by state standards and high-stakes testing, they have little time to experiment with diverse methods and ideas to find those that work (Weiss, Pasley, Smith, Banilower, & Heck, 2003). Educators have neither time nor money to waste on those ideas that produce no results. One of the methods long accepted, perhaps blindly, as valuable is the use of hands-on laboratory experiences (also referred to as labs) in the teaching of science (Hart, Mulhall, Berry, Loughran, & Gunstone, 2000; Shulman & Tamir, 1973). Students have engaged in labs in science classes since the turn of the 20th century (DeBoer, 1991; Duschl, 2004), but despite the 97% of science teachers who believe these activities are an essential part of the science curriculum (Weiss, 1993), little improvement has thus far been measured on test scores or other cognitive indicators. (Coleman, 1986; Hofstein & Lunetta, 1982, 2004; Yager, Engen, & Yager, 1969).

Statement of the Problem

In the realm of science education, real disagreement has occurred about the efficacy of laboratory work (Hodson, 1990, 1992; Hofstein & Lunetta, 1982; Lazarowitz & Tamir, 1994; National Research Council, 2006). Some feel all learning should derive from laboratory work; others feel it is useful only for verifying or confirming concepts already learned in lectures. Some think it is useful only to show what real science looks like; others say it does the exact opposite. Some teachers find laboratory work absolutely necessary; others find it unnecessarily burdensome. Some students say they enjoy
laboratory work; others say they hate it. National standards have indicated that all
learning must be experiential, but much of the educational research upon which these
standards are based has demonstrated no particular value in performing hands-on
activities.

The major force in science education at the time of this writing was the *National
Science Education Standards* (National Research Council, 1996), whose authors
emphasized laboratory instruction and other hands-on activities: “Learning science is
something students do, not something that is done to them. . . . Science teaching must
involve students in inquiry-oriented investigations in which they interact with their
teachers and peers” (National Research Council, 1996, p. 20). Research on lab
effectiveness, however, has failed to support this relationship: “The links between the
hands-on activities and the development of meaningful conceptual understandings were
elusive in many classrooms” (Kuhn, 1993, p. 336). A clear disparity has emerged
between what research has shown and what proponents of a research-based initiative
have proposed.

A major component in the discussion of the place of laboratory work in science
education is absent. Most of the available research was conducted by means of
quantitative methodology, focusing on cognitive gains measured primarily by test scores.
Perhaps this type of research has been acceptable to science educators because it
coincides with the nature of most scientific experimentation. When examined in this
light, laboratory work has repeatedly failed to show much value through the decades
(Coleman, 1986; Hofstein & Lunetta, 1982; Millar, 2004; Roth, 1994; Stake & Easley,
Bracketing the last four decades of this work, in fact, are the following statements: “The laboratory approach seems to provide no measurable advantages over other modes of instruction other than in the development of laboratory skills” (Yager et al., 1969, p. 85) and “The assumption that laboratory experiences help students understand materials, phenomena, concepts, models, and relationships, almost independent of the nature of the laboratory experience, continues to be widespread in spite of sparse data from carefully designed and conducted studies” (Hofstein & Lunetta, 2004, p. 46). Such conclusions leave the proponents of laboratory exercises with the problem “of defending laboratory activities as an essential component of the science curriculum” (Blosser, 1983, p. 168).

Earlier research cannot be summarily dismissed, yet I propose that some facets of the current research knowledge base are missing. Teachers have sensed a gap between what current research has shown and what must happen in their classrooms: “Laboratory work is almost ubiquitously seen as being of great importance to science education, by some as almost the defining characteristic of this component in the school curriculum” (Hart et al., 2000, pp. 655–656). To this end most high school science students participate in some type of laboratory experience at least once per week (Smith, Banilower, McMahon, & Weiss, 2002). As noted above, proponents of the National Science Education Standards have emphasized laboratory work, and teachers have typically asked students to engage in it; yet the potential results of this work have yet to be either realized or illuminated.

A recent government report provided a clear example of the “missing information.” One of the two major documents on laboratory work in schools completed
in the last 5 years, a comprehensive study of this subject, was entitled *America’s Lab Report: Investigations in High School Science* (National Research Council, 2006). The framers of the report, prepared by members of the National Research Council (NRC) and cosponsored by the National Academies of Sciences and the National Science Foundation, were charged with the following:

Given the long history of laboratories in school science, the absence of consistent and well-grounded research on high school labs is troubling. *America’s Lab Report* begins to fill this important void. . . . *America’s Lab Report: Investigations in High School Science* is born of hours of sustained examination of a broad body of evidence by a diverse and uniquely qualified group of experts. The result is a previously unavailable synthesis of research that supports a compelling discussion of the evolving role of laboratories in advancing the goals of science education. (National Research Council, 2006, p. viii)

When defining the goals of laboratory experiences, this diverse group, which included many recognized contemporary researchers, concluded the following:

In our review of the literature, the committee identified a number of science learning goals that have been attributed to laboratory experiences, including

- Mastery of subject matter,
- Developing scientific reasoning,
- Understanding the complexity and ambiguity of empirical work,
- Developing practical skills,
- Understanding the nature of science,
• Cultivating interest in science and interest in learning science, and
• Developing teamwork abilities (National Research Council, 2006, p. 3).

Examination of these goals reveals two problems. First, few of them can be effectively measured with the multiple-choice questions typically used by classroom teachers. Although scholars may disagree on the precise number that could be measured with common quantitative methods, most (six of the seven, in my opinion) can be verified neither well nor completely this way. Second, many of the foregoing goals for laboratory instruction lack a solid research base as do others mentioned elsewhere in the literature, such as motivation, excitement, classroom climate, and enthusiasm (Hofstein & Lunetta, 1982; Wellington, 1998). Searching for new dimensions that support these positive outcomes requires paradigms and research methods that suit the question.

In light of these realities, I chose qualitative methodology for this study because “understanding causal processes and mechanisms requires close attention to contextual factors and, . . . capturing these complexities typically involves qualitative modes of inquiry” (Feurer, Towne, & Shavelson, 2002, p. 8). In this study I attempted to reach beyond the easily measurable because if scholars continue to think, theorize, and research in familiar ways, the results will undoubtedly be familiar. Wilson and Stensvold (1993) stated:

It is probably true that, for some students, an appropriate passage of text or lecture might provide a more direct conveyance of the knowledge than a similar experience in laboratory. If that is all that is considered or evaluated, then the assessed result will be a forgone conclusion. (p. 426)
Investigation beyond that which is typically “considered and evaluated” is absent in the contemporary knowledge base. Lack of such investigation constitutes the problem and provides the rationale for this study.

Purpose of the Study

At a conference I attended in 1994, a presenter showed some results of a survey on laboratory instruction given to teachers, indicating that they believed labs to be both fun and valuable. The presenter, however, wondered off-hand whether students thought the same. In truth, most past and current studies have focused primarily on the following stakeholders: teachers, scientists, and the community at large. Notably absent is the student perspective, which is infrequently mentioned and only with regard to some other issue, such as the teacher’s objective for the lab. The voice of a major stakeholder in the process of education is absent. The purpose of this study was, therefore, to investigate an under-researched area of school science laboratory work, specifically the viewpoint of the student toward laboratory experiences.

Students’ attitudes towards laboratory experiences have been classified by numerous scholars as aspects of the affective domain (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956; Krathwohl, Bloom, & Masia, 1956). The importance of affect in supporting the value of laboratory experiences has also been well established. Shulman and Tamir (1973) wrote of “the importance of affect, imagination, intuition, and attitude as outcomes of science instruction as at least as important as their cognitive counterparts” (p. 1139); but Hofstein and Lunetta (2004) documented the opposite trend in the second of their seminal works on laboratory instruction: “Nevertheless, beginning in the 1980s,
the pendulum of scholarly research attention within the science education literature moved away from the affective domain and toward the cognitive domain in general and toward conceptual change in particular” (p. 34). Still,

science education literature continues to articulate that laboratory work is an important medium for enhancing attitudes, stimulating interest and enjoyment, and motivating students to learn science. The failure to examine effects of various school science experiences on students’ attitudes is unfortunate since experiences that promote positive attitudes could have very beneficial effects on interest and learning. (Hofstein & Lunetta, 2004, p. 34)

The general sense and framework of this study echo the words of these scholars. Illuminated by this study, the affective domain is an important factor in determining the value of an activity as well as how the student perspective on these activities works in this domain. I found support in Wallace and Kang (2004):

We need to know more about both the cognitive and affective influences of inquiry on science learning, including motivation, science identity, creativity, conceptual growth, scientific thinking, and nature of science understandings. Studies of student response to inquiry should take place in classrooms where teachers are currently implementing inquiry within the constraints of school culture, rather than special camps, classes, or programs. (p. 959)

The specific purpose of this study, then, is to illuminate the student perspective on laboratory activities. Several scholars have included comments from students, and a few have even interviewed them; but all the comments were judged in terms of the researcher
or the teacher. In other words, a few studies mentioned why the researcher thought students found value (or not) in labs, and a few stated why teachers thought students found value (or not) in labs; but insight from the students themselves is absent. Researchers and teachers possess a great deal of knowledge, experience, and insight; yet the students live the experience, and their insight, honesty, and candor are equally important pieces of data. Hofstein and Lunetta (2004) stated, “It is important to acquire information and insight about what is really happening when students engage in laboratory activities, i.e., we need to examine what the students are perceiving in the light of important goals for science learning” (p. 38); and “teachers need ways to find out what their students are thinking and learning in the science laboratory and classroom” (p. 49).

To summarize, in this study I have researched student perspectives on laboratory activities. I have sought to understand the following: What is the value of these activities from the student’s standpoint? What is wrong with these activities from the student’s standpoint? What could be done to make these activities better from the student’s standpoint? The purpose was to uncover the undocumented or under-documented value of these activities. Of course, the possibility existed that value may not have been found, or worse, that from the student’s point of view these activities may have hindered learning. Fortunately, this was not the case; instead I discovered important information, which can increase the value of these activities. Only with a thorough look at students’ viewpoints can other pieces of the puzzle called science education be put into place and allow practitioners (teachers) to make effective decisions on what they teach, how they teach, and the overall curriculum itself. Just a few vital pieces of information could lead
to new avenues of research and heretofore unrecognized ways to teach students more effectively.

**Research Question**

Formulating an effective, succinct research question is difficult in a study based on grounded theory methodology, which has been discussed at length in chapters 2 and 3. Two of the originators of this methodology defined the research question as follows: “The research question in a grounded theory study is a statement that identifies the phenomenon to be studied” (Strauss & Corbin, 1990, p. 38). The other originator of this methodology, Barney Glaser, colorfully noted that researchers do not start with a research question but with “abstract wonderment” (1992, p. 22) and let the research question emerge. My “phenomenon to be studied” and my “wonderment” were the high school student’s perspective on laboratory experiences. Discovering the nature of this perspective and from that the implications of this perspective for modern science education set the boundaries of this study as much as possible in grounded theory methodology.

**Definitions**

The most important term requiring definition for this study is laboratory activity, especially vital in light of the first major conclusion drawn by the National Research Council (2006) in *America’s Lab Report*—that “researchers and educators do not agree on how to define high school science laboratories or on their purposes, hampering the accumulation of evidence that might guide improvements in laboratory education” (p. 1). Hofstein and Lunetta (2004) defined laboratory activities as “learning experiences in
which students interact with materials and/or with models to observe and understand the natural world” (p. 31). The members of the NRC, apparently drawing on this definition, expanded it to encompass “opportunities for students to interact directly with the material world (or with data drawn from the material world), using the tools, data collection techniques, models, and theories of science” (2006, p. 3). Given the similarity between these definitions, the brevity and simplicity of the Hofstein and Lunetta (2004) definition make it the working definition for this study.

Researcher Assumptions

Although most of the assumptions in this type of study were emergent in nature and addressed as they emerged, I held several basic assumptions from the outset. First and foremost, I assumed the inherent value of the student perspective. The possibility existed that all conclusions to be drawn by giving voice to the student perspective had already been illuminated by others, that the student had nothing more to say than the researcher and teacher had already articulated. The core category eventually emerging in this study was not a new idea, but the emphasis placed on it by students may be surprising, illuminating, and valuable to science educators reflecting on their practice.

I also faced the possibility that my conclusion might have been of little educational value to others. This study was bound by its context, and because the researcher was a data source, bound by the vagaries of the researcher. As in most studies the best the researcher can accomplish is transparency, which I maintained by explaining the context of the study and my thought process via researcher memos. Individual readers may determine value for their own context.
A related assumption and possible limitation was that the context was influenced by the researcher himself. As an active science teacher at the school studied it is possible my relationship with the students could shape their answers. I address this issue in the discussion of validity and making my methods transparent.

I made some assumptions because the primary data sources were students. When the student voice is primary, their purposes and the purposes of their teachers may not only be different but also at odds and may produce data of interest in sociology or other circles, having little impact on improving science education. Students and researcher differed widely in age and vocabulary, making understanding one another an issue; and misunderstanding can lead to faulty data. Assumptions also included honesty and candor. The students might try to undermine the study or fail to take the idea seriously or more likely try to say what they believed the researcher wanted to hear.

Other assumptions regarding the issues of validity and reliability will be addressed in chapter 3 on methodology.

Organization of the Study

The research gaps I wished to fill with this study were twofold: first, previous studies of the value of laboratory work in science classes have been lacking; and second, the manner in which it has been studied was one-dimensional. In chapter 2 I have provided a brief history of the literature base as of 2008, in which the student perspective was clearly missing. In both chapters 2 and 3 I used the multidimensional nature of the data as a justification for the qualitative methodology of this study. Chapter 4 contains all of the data comprising the student perspective and concurrent data analysis as required by
grounded theory methodology. This study concludes with chapter 5, in which I discussed possible implications and avenues for further research.
CHAPTER 2
LITERATURE REVIEW

Overview

School science laboratory experiences are well established in science curricula. Likewise, research into their effectiveness has been ongoing for decades (Coleman, 1986; DeBoer, 1991; Duschl, 2004). This research can be neatly divided in two. Early research accompanied the emergence of laboratory activities in the early 1900s, peaked, and then waned in the 1960s. A new era of research dawned in the mid 1980s, caught in the storm of educational reform sparked by *A Nation at Risk*, the report of the National Commission on Excellence in Education (1983). This emphasis on reform sparked many projects important to this study, such as a position statement from the National Science Teachers Association (1990), Project 2061 from the American Association for the Advancement of Science (1995), and of course, the *National Science Education Standards* (National Research Council, 1996). Despite the continued weight of hands-on activities in projects such as the *National Science Education Standards* and the *No Child Left Behind Act* of 2001, research into laboratory effectiveness was once again waning at the time of this writing. An exploration of the literature underscores the need for this study.

Early Research on Laboratory Effectiveness

Early research on the effectiveness of laboratory experiences emerged in the early 1900s with a series of experiments that continued through the 1920s. Researchers
investigated whether or not using laboratory activities was worth the extra expense and effort they required. In other words, they sought to determine whether laboratory activities resulted in more cognitive gains (an increase in test scores) than other, less expensive methods, such as lecture and demonstration, a question lingering at the beginning of the 21st century (see National Research Council, 2006, p. 199). From 1918 (Wiley, 1918) through the 20s (Carpenter, 1925; Cooprider, 1923; Horton, 1928), researchers failed to show any positive results among students engaging in laboratory experiences. Lacking evidence of an increase in test scores, the primary rationale for maintaining an educational program (then as now), these studies could not justify laboratory activities in the curriculum.

Fortunately, the educational progressives of the 1930s and 40s did not end the practice of lab exercises. Openness to other worthwhile outcomes was shown in this passage from the National Society for the Study of Education in 1932:

It is very probable that experimenters have not yet been able to measure the more valuable outcomes of laboratory instruction, as a number of critics have pointed out. If there are valuable outcomes, the added expense needed to secure them may be justified, but just how valuable the laboratory experience as a whole may be, we do not yet know. (p. 270)

This prevailing attitude led researchers to look for some of these “valuable outcomes” that had yet to be discovered. Some researchers were marginally successful in locating some untested outcomes, such as increases in student resourcefulness (Goldstein, 1937) and student manipulation skills (Kruglak, 1952). Others failed, for example,
Edmiston and Braddock’s (1941) attempt to find a correlation between student attentiveness and use of laboratory activities. One problem with these studies was that any positive results were limited in scope to those pursuing careers in science. Whether or not such gains were worth the costs was still debatable. Results that crossed boundaries to include those pursuing other careers were needed, in other words results that were “valuable” or “important” to all.

Two studies pursued value beyond test scores even though what was “important” eventually reverted to these same scores. Two new outcomes, ill-defined at the time, were illuminated in 1966 by Coulter, who demonstrated that students participating in inductive labs (labs where the process is more open) showed an increase in science inquiry skills. Likewise, Sorensen (1966) found an increase in critical thinking skills in groups using laboratory activities over those exposed only to the lecture–demonstration method. At the time of this writing, finding more important words in science education than inquiry and critical thinking would be difficult, but the climate in the 60s had changed once again; and these studies lost much of their importance because they lay outside the prevailing paradigm.

What was important shifted once again with the launch of Sputnik in 1957. Increasing test scores was of primary importance. In a meta-analysis of the research done up to 1970, Coleman (1986) looked at 13 variables tested (including recall, retention, application, understanding, etc.) and concluded that “only one of the 13 outcomes, laboratory manipulative skills, showed a strong indication of significant results in favor of the laboratory method” (p. 135). The results seemed conclusive: “Gradually the
number of studies declined and finally ceased in 1970 when nothing more appeared to be gained from further research” (p. 118). Laboratory activities simply did not reach their expected primary goal of increasing test scores (Stake & Easley, 1978; Welch, 1981).

Bates (1978) asked the quintessential question for this early research and for this study as well: “What does the laboratory accomplish that could not be accomplished as well by less expensive and less time-consuming alternatives?”

Labs, however, survived this period, and perhaps teachers and researchers alike knew or at least sensed the importance of more (other paradigms) than test scores; or perhaps they sensed a new perspective was needed to see the results that were as yet undetected. The belief that “more [was] to be discovered” remained through early 21st-century research on laboratory activities and served as the foundation for this study.

Current Research on Laboratory Effectiveness

The first call to renew research on laboratory activities was made in an important research summary by Hofstein and Lunetta in 1982, highlighting “neglected aspects of research” in their title. They noted that valuable outcomes were indeed hard to find, but most of the previous research fell short of expectations and better studies were needed. They believed that viable research would show that laboratory work is successful in promoting or developing (a) logic, (b) inquiry and problem solving skills, (c) manipulative skills, (d) observational skills, and (e) positive attitudes toward science (Hofstein & Lunetta, 1982, p. 212).

But this new call was not enough to produce results. Hodson (1990) found no gains in effectiveness in the student laboratory, and Kuhn (1993) agreed that “the links
between the hands-on activities and the development of meaningful conceptual understandings were elusive in many classrooms” (p. 336).

Simultaneously many studies showed what has gone awry in the laboratory. Labs have been described as “dull and teacher directed,” and researchers have found that “students often failed to relate the laboratory work to other aspects of their learning” (Hart et al., 2000, pp. 655–656). The work of the lab involved “mechanical performance of routine tasks with little concern for and understanding of the purpose and logic which underlie the various activities” (Rubin & Tamir, 1988, p. 477). Regarding the results of labs, “students may see what they expect to see and not what is actually before them” (McComas & Moore, 2001, p. 246).

Although much of the research was negative, some researchers reconceptualized lab work in new, more effective ways. Renner, Abraham, and Birnie (1985) suggested that discussion following the lab was critical. Butts, Hofman, and Anderson (1994) agreed that “‘hands-on’ experiences need to be coupled with instructional conversations” (p. 12). Tobin (1997) noted, “What is important here, as in all activities, is that students understand what they are doing and why they are doing it” (p. 389). In other words, how teachers teach may change the results or effectiveness of the lab (Sutman, Schmuckler, Hilosky, Priestley, & Priestley, 1996; Tamir, 1989).

Finding new facets of the lab entailed more than procedural issues. The traditional idea of scientific inquiry was reintroduced and gained prominence. “Used properly, the laboratory is especially important in the current era, where inquiry has re-emerged as a central style advocated for science teaching and learning” (Hofstein & Lunetta, 2004, p.
Earlier Hofstein (1988) had suggested that laboratory activities improve inquiry and problem-solving skills, a belief echoed by Herron and Nurrenbern (1999), who stated, “Inquiry-oriented laboratory activities teach inquiry better than lecture/demonstration or verification lab exercises, but only if teachers are skilled in inquiry teaching methods and students are given the time and guidance required” (p. 1358). Millar (1989) linked the last two ideas, stating that with procedural improvements the dual role of laboratory activities would emerge as “facilitating the learning and understanding of science concepts and in developing the skills and procedures of scientific enquiry” (pp. 38–39). Recent researchers have suggested that well-done labs promote scientific inquiry (McComas, 2005).

Also bolstering the image of the lab was constructivism, the learning paradigm that became the model of choice for many science educators (Hofstein & Lunetta, 2004; Lunetta, 1998). The basic tenet that “learners construct their ideas and understanding on the basis of series of personal experiences” (Hofstein & Lunetta, 2004, p. 32) seemingly fit well with laboratory activities (see Driver, Squires, Rushworth, & Wood-Robinson, 1994; Roth, 1995; Tsai, 1999; Wheatley, 1991). Tobin (1990) stated, “Laboratory experiences allow students to learn with understanding and at the same time engage in the process of constructing knowledge by doing science” (p. 405). Lazarowitz, and Tamir stated in the 1994 edition of Handbook of Research on Science Teaching and Learning: The major characteristics of learning in the laboratory are that it is based on concrete experiences, involves hands-on activities, and makes use of the senses.
This kind of learning may be designated as “experiential learning,” which is consistent with constructivist views of the learning process. (p. 119)

Although constructivism has been regarded as an overused, broadly defined, and often misunderstood concept, it has been useful in the research of laboratory activities and maintaining attention on them.

The *National Science Education Standards* require activities that are both inquiry-oriented and hands-on, attributes amenable to the influential constructivist model; thus, it is important to question whether laboratory activities have finally been affirmed and researched to the point of general acceptance. The authors of two seminal works have proposed an answer.

Hofstein and Lunetta (2004), whose insights are woven throughout this work, published a second influential work in this area more than 2 decades after their first in 1982. Summarizing the research to date, they stated, “It is disappointing to note the continuing limitations in systematic scholarship associated with such a central medium as the laboratory in science education” (2004, p. 48); they pointed out deficiencies in research on new technologies (p. 42), improper assessment of laboratory outcomes (p. 43) and practical knowledge (p. 44), untested assumptions on student understanding (p. 46), and the lack of using recent theories of learning (p. 47). All these areas have invited new research, but of primary importance for this study was their call “to acquire information and insight about what is really happening when students engage in laboratory activities, i.e., we need to examine what the students are perceiving in the light of important goals for science learning” (p. 38). They concluded that
teachers need ways to find out what their students are thinking and learning in the
science laboratory and classroom [and that] empowering professional teachers in
these roles and encouraging relevant research on central issues like supporting
and assessing the effectiveness of the school science laboratory are very important
next steps that warrant attention from professional societies, higher education,
school administrators, and teacher certification bodies. (p. 49)

This call was the directive for this study.

The other recent major work on laboratory activities is *America’s Lab Report*,
published by the National Research Council (2006). The committee gathered reports from
most of the top researchers in the field (see Bell, 2004; Duschl, 2004; Lynch, 2004;
Millar, 2004). The authors of *America’s Lab Report* (National Research Council, 2006)
came to seven major conclusions, ranging across the spectrum on the subject from broad
criticism of state standards and assessment (p. 9) to the narrow definition of laboratory
activities (p. 3), from the poor quality of the experiences themselves (p. 6) to instructional
choices of the teacher (p. 6), and from impediments caused by school structure and
organization (p. 8) and to improvements needed in undergraduate education (p. 7).

But like Hofstein and Lunetta, the framers of this report, drew a conclusion about
what was still left unknown to this point. The authors asserted, “The state of the research
knowledge base on laboratory experience is dismal but, even so, suggests that the
laboratory experiences of most high school students are equally dismal” (National
Research Council, 2006, p. 199). They opened the report by citing “gaps in the research
and in capturing the knowledge of expert science teachers make it difficult to reach
precise conclusions on the best approaches to laboratory teaching and learning” (National Research Council, 2006, p. 2). They furthermore stated that “a serious research agenda is required to build knowledge of how various types of laboratory experiences (within the context of science education) may contribute to specific science learning outcomes” (National Research Council, 2006, pp. 8–9) and concluded by stating a major goal of “continuing learning about laboratory experiences” (p. 200). Also like Hofstein and Lunetta, they called for partnerships to work on filling this knowledge gap: “Specifically, teachers, scientists, cognitive psychologists, education researchers, and school systems, working together, are best able to design and test innovative approaches to laboratory experiences” (National Research Council, 2006, p. 200). This study fits well with their conclusions and recommendations for further research.

The authors of these seminal works and numerous others mentioned earlier have clearly affirmed research need. They have pointed out both methodological and knowledge gaps, which I have endeavored to close with this study.

**Closing the Methodological Gap: A Grounded Theory Review**

Most of my focus above has been on the type of data missing from the knowledge base, but as I asserted in the introduction, the data is also methodologically skewed by the prevalence of quantitative studies. The literature review has pointed to a need for data in areas not easily measured this way. Many aspects of this type of research reside in the affective domain (Krathwohl et al., 1956; Wellington, 1998) and revolve around words difficult to define, such as *excitement, enjoyment, motivation, interest, spirit, soul*, and *enthusiasm*. Measurement is also difficult because numbers on a test are inadequate, and
what measures a researcher takes are often contextual in nature. In fact Ausubel (1968) and Yager et al. (1969) argued that data cannot be measured out of context, a line of thinking reiterated in Hofstein and Lunetta’s (2004) observation of the “growing sense that learning is contextualized” (p. 32).

Data must be collected in the qualitative realm, but few researchers have moved in this direction (Gardner & Gauld, 1990). In the past the separation between qualitative methods and quantitative methods was sharply defined and bitterly argued, but that distinction has faded. Questions about and differences in ontology and epistemology are viewed as more fundamental than questions of method, such as qualitative versus quantitative data collection (Guba & Lincoln, 1994). Even some of these distinctions have been recently blurred (Lincoln & Guba, 2000). Morse and Richards (2002) stated, “We see no chasm between qualitative and quantitative techniques. It is our experience that many qualitative projects involve counting at some stage, and many questions are best answered by quantification”; but they added that “qualitative methods are the best or only way of addressing some research purposes and answering some sorts of questions” (p. 27).

Morse and Richards (2002) cited the common call in most research methodology books today: to choose the method or techniques that best fit the data, research question, or problem. Thus the question is not about the relative strength or weakness of individual methodologies but simply one of fit. This literature review has shown that relatively little is known about the efficacy of laboratory work in science classes; given that, my choices narrowed. In a work on grounded theory, Glaser (1992) described the fitting process as
follows: “Qualitative methods can be used to uncover the nature of people’s actions and experiences and perspectives which are as yet little known in the world of research products” (p. 12). Morse and Richards (2002) echoed:

If the purpose is to understand an area where little is known or where previously offered understanding appears inadequate (thin, biased, partial), you need research methods that will help you see the subject anew and will offer surprises. Put bluntly, if you don’t know what you are likely to find, your project requires methods that will allow you to learn what the question is from the data. (pp. 27–28)

This statement not only ties my research question to qualitative techniques but also alludes to grounded theory methodology, which is an excellent choice if little is known about the research question or if an old problem calls for a new approach (Hutchinson, 1988).

The history of grounded theory has been detailed by its originators, Barney Glaser and Anselm Strauss (Glaser & Strauss, 1967; Glaser, 1992; Strauss & Corbin, 1998), and the numerous authors who followed (Charmaz, 2000; Creswell, 2002; Hutchinson, 1988). Introduced in the 1960s, the methodology was designed to combine qualitative data with the rigors of what was considered “good science” at the time.

Grounded theorists share their conviction that the usual canons of “good science” should be retained but require redefinition in order to fit the realities of qualitative research, and the complexities of social phenomena that we seek to understand. (Strauss & Corbin, 1990, pp. 249–50)
The methodology was named for its use in generating theories that are grounded in the data; “the value of [grounded theory methodology] lies in its ability not only to generate theory but also to ground that theory in data” (Strauss & Corbin, 1998, p. 8). Although the methodology has evolved (Strauss & Corbin, 1994) in different directions at times, a few aspects have remained constant.

From the outset the foundation of grounded theory has lain in the continuous comparison of the data with itself, with developing categories, and with the emerging theory during all phases of the study; that is, it is “a general method of [uninterrupted] comparative analysis” (Glaser & Strauss, 1967, p. vii) or “continuous interplay between analysis and data collection” (Strauss & Corbin, 1994, p. 273). In other words, data collection and data analysis occur simultaneously. As theories emerge from the data, they are tested against new data, which may shape or dispute the theory; and the cycle continues, eventually generating a “theory” that is “grounded” in the data. “They (data collection, data analysis, and data presentation) constantly adjust [one another] to the emergent theory . . . in order to stay close to the data yet to conceptualize it” (Glaser, 1992, p. 14). Huberman and Miles (1994) called this the “cycle of inductive data collection and analysis and deductive testing and verification” (p. 438), alluding to the second constant in all grounded theory—the inductive nature of the research. Instead of launching a study with a broad theory, then testing specifics, those who implement this method begin with specific points of data, and then allow that data to induce a broader idea called a theory. Strauss and Corbin (1990) affirmed this process:
A grounded theory is one that is inductively derived from the study of the phenomenon it represents. . . . One does not begin with a theory, then prove it. Rather, one begins with an area of study and what is relevant to that area is allowed to emerge.” (p. 23)

Glaser succinctly summarized the point of grounded theory: to “generate an inductive theory about a substantive area” (1992, p. 16; see also Patton, 2002, p. 125).

Other factors common to most grounded theory research include theoretical sensitivity, open coding, theoretical sampling, selection of a core variable, and saturation. These have been discussed in chapter 3.

Glaser and Strauss eventually took their grounded theory methodology in different directions (Babchuk, 1997). The bifurcation was fully documented in the two works they published: Basics of Qualitative Research: Grounded Theory Procedures and Techniques by Strauss and Corbin (1990) and Glaser’s rebuttal, Basics of Grounded Theory Analysis: Emergence vs. Forcing (1992). Glaser fundamentally disagreed with the procedures and techniques that Strauss and Corbin recommended; he insisted that implementing them could cause the researcher to miss the relevance of the data by forcing them into a preconceived framework. As a researcher Glaser (1992) wanted to “humbly allow the data to control him as much as humanly possible” (p. 87). Later many agreed to varying degrees. Denzin and Lincoln (1994) accused Strauss and Corbin of attempting to modify positivistic ideals of good science into a postpositivistic conception of rigorous research. Others have called Strauss and Corbin’s guidelines “didactic and
prescriptive rather than emergent and interactive” (Charmaz, 2000, p. 524) and even elaborately algorithmic (Tuettemann, 2003).

In response to Glaser’s claims, Strauss and Corbin (1994, 1998) stated that although their primary focus was to help the beginning researcher, they insisted that they had continuously pointed out the need for openness and flexibility (1990, p. 26) and that the adaptation and altering of their techniques was responsive to the data (1994, p. 276). To emphasize their point, they stated the following in the foreword of the second edition of their 1990 book:

This is not a recipe book to be applied to research in a step-by-step fashion. Our intent is to provide a set of useful tools for analyzing qualitative data. We hope that through our examples, readers will come to realize the fluid and flexible approach to data analysis provided by this method. (1998, p. xi)

This call for flexibility in design and the demise of rigid rules have been reflected by other researchers (Creswell, 2002; Patton, 2002). In their discussion of paradigm controversies such as this, Lincoln and Guba (2000) noted that various methodologies “interbreed” and are “inevitably interwoven” (p. 164); researchers have, in fact, bade “farewell to criteriology” (p. 179). Perhaps thinking has reverted to what Hutchison said before the controversy: “Grounded theory research strivestobe paradigm transcending” (1988, p. 123).

In her recent argument for a third type of grounded theory based on constructivist ideas, Charmaz (2000) summarized what has happened and pointed to a possible evolution of grounded theory:
My argument is threefold: (a) Grounded theory strategies need not be rigid or prescriptive; (b) a focus on meaning while using grounded theory furthers, rather than limits interpretive understanding; and (c) we can adapt grounded theory transcending without embracing the positivist leanings of earlier proponents of grounded theory. (p. 510)

Flexibility, creativity, adaptation, interbreeding of methodologies, and fitting the techniques to the data constitute the future of grounded theory. We can use ideas from Glaser, from Strauss and Corbin, and from Charmaz; they all can be integrated not only into an overall research process but also into grounded theory methodology. In fact, in a recent methodology text (Creswell, 2002) grounded theory was described as one methodology with three subcategories: (a) systematic design (Strauss and Corbin), (b) emergent design (Glaser), and (c) constructivist design (Charmaz). The ideas can easily coexist. In the original work on grounded theory, Glaser and Strauss (1967) admitted that all theory must be modifiable. Perhaps the same should be said of their own methodology.

The Possibility of a Converged Grounded Theory

Even the partial convergence of differing perspectives on grounded theory can accommodate those foundations noted above and yet allow for the best and correct method of data collection, data analysis, and data presentation in the research. The various perspectives still operate on the same foundation and point to the same end—the generation of theory based in data. What results is the possibility of generating relevant theory in an area minimally explored to this point. The theory generated has been labeled
middle-range (Charmaz, 2000); in other words, it is not some overarching theory on human behavior, but neither is it a “minor working hypothesis” (Glaser & Strauss, 1967, p. 33). This level of theory is what is most needed on the front lines of education today. Most grand theories on human behavior are so broad that they leave teachers in need of practical applications and techniques to use (Creswell, 2002). Other research can be so limited by its context or its lack of theoretical foundation that it doesn’t allow for translation into the teacher’s setting. This is the compromise I attempted to reach in this study—to have enough theoretical foundation to allow my research to be used by or at least reflected upon by others yet to work at the level where teachers and others can perceive substantial application to their work. In this I echo Hutchinson (1988), who said, “Clearly there is a need for middle-range (between theory-testing verification studies and atheoretical process–product studies) data-based theory in education that explains the everyday world of teachers, students, administrators, and the school bureaucracy” (p. 126).

Hutchinson also put a fine capstone on the discussion of grounded theory methodology and its place in theory development for education:

Grounded theory offers a systematic method by which to study the richness and diversity of human experience and to generate relevant, plausible theory which can be used to understand the contextual reality of social behavior. With such understanding, educators can assess what is happening in the groups studied and plan interventions to improve the quality of education. (p. 127)

This study mirrors Hutchinson’s assessment
CHAPTER 3
RESEARCH DESIGN

Introduction

Reviewing the literature on laboratory experiences and on grounded theory methodology revealed the two major gaps I have attempted to fill with this study: (a) the gap in the knowledge base resulting from the omission of the student perspective, and (b) the gap in methodology resulting from the prevalence of quantitative studies and resultant exclusion of context surrounding the data. The purpose of this study was to narrow these gaps by using grounded theory methodology with the student as a primary data source. Although framing a concise research question is methodologically difficult at the outset of a study, I initially identified the “phenomenon to be studied” (Strauss & Corbin, 1990, p. 38) and the “abstract wonderment” (Glaser, 1992, p. 22) that was required to set the study in motion and posed the following question: How do students perceive high school laboratory experiences?

Study Overview

Perhaps Charmaz (2000) has best and most succinctly stated the foundations of grounded theory, the methodological framework guiding this study:

The strengths of grounded theory methods lie in (a) steps that guide the researcher step by step through an analytic process, (b) the self-correcting nature of the data collection process, (c) the methods’ inherent bent toward theory and the
simultaneous turning away from acontextual description, and (d) the emphasis on comparative methods. (p. 522)

This study took place from spring 2007 to spring 2008. Following acceptance of the proposal and approval by the Institutional Review Board, the study commenced with field observations of students during lab work and lab analysis. Charmaz pointed out that grounded theory researchers are to be “distanced experts” (p. 513); thus, the purpose of these observations was simply to bring my clouded and biased thinking to focus on the student perspective. Field notes of these observations and their concurrent analysis led to the next stage of this study: a questionnaire for all the participants designed to ascertain their perspective on labs. The questionnaire (Appendix A) consisted of several demographic questions (e.g., year in school, number of science classes) along with a few multiple-choice questions to yield some quantifiable data on the student perspective. These questions were constructed in order to discover the students’ favorite classroom activities and their attitude toward laboratory experiences. The remainder of the survey consisted of open-ended questions asking about students’ likes and dislikes and soliciting suggestions for the improvement of laboratory experiences. Their answers were coded and categorized according to grounded theory methodology, described later. The last phase of the study consisted of 12 formal interviews for the purpose of refining the emerging core category, and eventually, identifying an emerging theory. Because of the multiple purposes of the interviews, the selection of the interviewees was based on matching the purpose, following the grounded theory methodology of theoretical sampling (see below). As a further check the emerging theory was presented to a focus
group of science teachers. The data from this focus group were used to test the feasibility of the emerging theory and guide the implications of the theory; the data and generated theory were then tested against other rigors of “good science” (Glaser & Strauss, 1967). A detailed description of the study follows.

Participants

The participants in this study were high school science students in a public high school in a city in the midwestern United States. The large state university located in the city influenced the demographics of the student population. At the time of this writing, the high school posted an average enrollment over 1,200 students in Grades 9 through 12. For the 2005–2006 academic year, student demographics reported to the State Department of Education included 84.9% White, 8.6% African American, 2.3% Asian or Pacific Islander, and 3.2% multiracial. Disadvantaged students constituted 17.6% of the student body, and 13.3% were reported as students with disabilities.

The participants in this study were enrolled in high school science classes. District requirements included passing three units of science, two of which were to be laboratory based. For this cohort of students, the state science requirement for graduation was three units of science, including one unit each of biological and physical science. Roughly 65% of the students in this school district enrolled in a fourth unit of science. Students followed three curricular streams through their high school years. Switching streams was permitted but rarely occurred. Self-identified noncollege-bound students typically enrolled in physical science, followed by biology and general science classes. Students on their way to college followed a traditional high school science sequence: physical
science, biology, chemistry, and physics. An advanced track was available for those who sought to pursue advanced biology, advanced chemistry, and advanced physics; Advanced Placement and advanced topics courses were available to students in their 4th year.

Sampling Procedure

The initial phase of the study—field observations—involved students in every stream at every grade level. Selection of the observations was randomized as much as possible. During my preparation times I visited numerous laboratory classes for 10 to 50 minutes depending on the length of the experience and the number of labs occurring at one time in the building. Ease of access to laboratory classes was a function of the collegiality among the science faculty. Although I did not observe every science class, these observations produced a sample including over 300 students representative of science students at this high school.

The resulting open-ended questionnaire was given to every science student in the high school near the end of the school year, usually immediately following a lab exercise. This yielded a diverse sample with over 800 possible data points.

As the study moved into the next phase involving student interviews, the sampling procedure followed the grounded theory technique of theoretical sampling. Strauss and Corbin (1990) defined theoretical sampling as “sampling on the basis of concepts that have proven theoretical relevance to the evolving theory” (p. 176) and later as “sampling on the basis of the emerging concepts, with the aim being to explore the dimensional range or varied conditions along which the properties of concepts vary”
Thus, in this phase I did not interview every possible participant. Sampling resulted from a conscious decision-making process (Hutchinson, 1988). To ensure representation, I selected three students from each grade and an equal number of males and females. The theoretical sampling grounded theory suggests was evident in the interview questions; the participants themselves did not need special selection. The interviews initially served the purpose of data required clarification. Later I needed data to further develop evolving categories, and I also looked for possible negative examples (see the flip-flop technique in Strauss & Corbin, 1990). Finally, I looked for the depth and reality of the emerging theory. Charmaz (2006) asserted, “Theoretical sampling pertains only to conceptual and theoretical development; it is not about representing a population or increasing the statistical generalizability of . . . results” (p. 101). Participants were chosen because they had something relevant to contribute to the process of generating theory, and others were not chosen because I believed they had nothing additional to contribute. Of course, I could have erred in the last assumption and missed something of importance; but with extended time in the field and in the data (what I have later identified as saturation), this became less likely. It remains a limitation of the study, however. Discriminate, theoretical sampling drove the final stages of the study.

Data Collection

For the sake of organizational simplicity, the sections devoted to data collection, data analysis, and rigor have been separated in this section. Recall, however, that grounded theory research is guided by a “constant comparative method of analysis”
Thus these sections do not represent distinct, linear stages but instead those that occur simultaneously and continuously; in fact, Morse and Richards (2002) combined data collection and data analysis into a step they called “making the data.” Although one may argue a distinction between the two, the reader of this type of methodology must remember how entwined these ideas remain in the study: “data collection and data analysis are tightly interwoven processes” (Strauss & Corbin, 1990, p. 59). Using the template suggested by Morse and Richards, I have included both data collection and its concurrent analysis in a single chapter (chapter 4).

**Observation and Interview**

Two of the major data collection techniques used in this study were the field observation and the interview. Although these two techniques are distinctly different and produce different data, the way they inform each other guided this study and its methodology. I found support in Hutchinson (1988), who said,

> Observing, by itself, is never enough because it begs misinterpretation. Interviews permit researchers to verify, clarify, or alter what they thought happened, to achieve a full understanding of an incident, and to take into account the “lived” experience of participants. (Hutchinson, p. 125)

In a way, not only does the interview clarify and verify the observation, but the observation also serves to clarify and verify the interview. Although the interview may have more depth, it lacks the breadth and spontaneity of field observations. Together in a cycle of data gathering and data analysis, data from one can shape data from the other as well as any emerging theory.
This study commenced with field observations involving nearly 300 students to assure that every grade level and science stream was observed. The technique used followed the guidelines of Atkinson and Hammersley (1994). The purpose of these observations at the outset of the study was to remove researcher bias and shift the perspective to that of the student. As the study progressed, the goal of the field observations also changed. Their purpose evolved into informing question formation (for the questionnaire), verifying and clarifying interviews, and verifying emerging theory. Because the continuous comparison of the body of data against itself is a key in grounded theory methodology, field observations continued until the end of data collection at the conclusion of the study.

The 12 formal interviews, which took place after the survey responses were coded and analyzed, served to deepen the analysis to that point. For example, an often coded response in the questionnaire indicated that students wanted to improve their understanding of the experience. The ambiguity of this answer led to an interview question asking what students meant: Did they merely want to understand the procedure, or something more, for example, to understand the point or objective of the experience? The interviews also informed the development of categories and codes delineated in chapter 4 and served the important work of helping shape and test emerging theory. The formal interviews (guided by Patton, 2002) involved a much smaller number of students than either the field observation or the open-ended surveys. The total number of interviews was determined by the number of interviews required to develop categories,
refine theory, and finally to test that emergent theory. The interview questions themselves were determined through the early field observation and data from the questionnaire.

*Open-Ended Survey*

Another important data collection technique was the open-ended survey (Appendix A) of all willing science students in the school, occurring near the end of the 2006–2007 school year. In this sense the survey was arguably a very broad but relatively shallow interview technique. One purpose of this technique was to make sure all perspectives were considered. In addition, the large amount of data was coded and categorized into some very informative groupings. Although counting was involved, it was simply “more data” (Glaser & Strauss, 1967), not an invasion of quantitative methods into a qualitative study. Strauss and Corbin (1998) stated: “We maintain that the aim of theorizing is to develop useful theories. So any technology, whether qualitative or quantitative, is only a means for accomplishing that aim. . . . An instrument is an instrument, not an end to itself” (p. 27). The questionnaire was not analyzed with sophisticated statistical techniques; quantifiable data was counted and charted, and the free responses were coded and eventually categorized. Notably, the foundation of the study was not this single type of data; however, this data proved very valuable, in many ways the most valuable data source. How it informed the other data was also invaluable.

*Memo Writing*

The last data collection technique that deserves mention was researcher memo writing. Memos not only show the researcher’s thinking on the data but also become data themselves. Often thoughts on data and the relationship of one piece of data with another
came at inopportune times and were fast and fleeting; they had to be captured before they were overwhelmed by other data (Hutchinson, 1988). All major authors on grounded theory have insisted on memo writing. Charmaz (2000) said that one of the strategies of grounded theory is “memo writing aimed at the construction of conceptual analysis” (p. 510); Glaser (1992) asserted the “prime rule is to stop and memo” (p. 83); and Strauss and Corbin (1990) added that “memos represent the written forms of our abstract thinking about data” (p. 198). Charmaz (2006) summarized best with the following: “Memo writing is the pivotal intermediate step between data collection and writing drafts of papers” (p. 72). This study has borne out the importance of researcher memos. Interspersed throughout the memos were entries in which researcher bias was noted and challenged. Because coding was in progress, future categories were mentioned throughout the memos, solidifying their prominence. Ironically, the eventual emergent theory appeared in embryonic form in the very first line of the very first memo I wrote.

Data Analysis in Grounded Theory Methodology

The “continuous interplay between analysis and data collection” (Strauss & Corbin, 1994, p. 273) was guided by theoretical sensitivity, a tenet of grounded theory. Thus, although theoretical sensitivity is not an actual data analysis technique, it is an overarching concept that permeates data analysis. Glaser (1992) wrote, “Theoretical sensitivity is an ability to generate concepts from data and relate them according to the normal modes of theory” (p. 27). Strauss and Corbin (1990) added that it is an “awareness of the subtleties of meaning of data” (p. 41) that comes from literature, professional experience, and personal experience. Charmaz (2000) simplified, calling it
an “integration of the theoretical framework” (p. 511). Theoretical sensitivity then is the constant awareness of emerging theory and the possibility of new theory during data collection and analysis. A “reciprocal shaping” (Strauss & Corbin, 1994, p. 280) occurs between the data and the researcher. The researcher brings to the data possibilities that the data shape, which in turn shape the way the data are viewed and so on. The originators of grounded theory summarized this point: “Generating a theory from data means that most hypotheses and concepts not only come from the data but are systematically worked out in relation to the data during the course of the research” (Glaser & Strauss, 1967, p. 6).

Coding

Coding of the data is the major data analysis technique used in grounded theory methodology. Coding is the “central process by which theories are built from data” (Strauss & Corbin, 1990, p. 57), and “coding starts the chain of theory development” (Charmaz, 2000, p. 515). Three levels of coding are involved in grounded theory: (a) open coding, (b) axial coding, and (c) selective coding.

Open coding. Open coding occurs first and most closely aligns with the common definition of coding in qualitative analysis (Huberman & Miles, 1994). Strauss and Corbin (1998) called this “the analytic process through which concepts are identified and their properties and dimensions discovered in data” (p. 101). Glaser (1978) simplified: “1) what are these data a study of, 2) what category does this incident indicate, 3) what is actually happening in the data, and 4) what accounts for the basic problem and process” (p. 57). At this point the researcher commences categorizing the data. This is an analysis
piece, in which the researcher through the lens of theoretical sensitivity takes the data and provides initial descriptions, notes properties, makes comparisons, and labels the data with a category. Glaser summarized: “The researcher has to be continually coding, comparing, analyzing and memoing while asking the sole question of the data: What category or property of category does this incident indicate?” (p. 19). He or she does not generate a theory about the data yet but instead simply finds and names the building blocks of a future theory.

Axial coding. Axial coding was best described by Strauss and Corbin (1990) as putting the “data back together in new ways by making connections between categories and subcategories” (p. 97) and “the process of relating categories to their subcategories, termed ‘axial’ because coding occurs around the axis of the category, linking categories at the level of properties and dimensions” (1998, p. 123). These statements indicate that axial coding focuses on the categories established during the open coding of the data. The researcher looks for relationships between the categories, working to discover how subcategories relate to their categories and how properties of the categories relate; in addition, the theoretically sensitive researcher looks for any connections that appear. Many researchers propose diagrams at this stage as a way to represent what is happening (Creswell, 2002); others (e.g., Glaser) do not. Inclined to “trust the data,” Glaser (1990) argued, “Categories emerge upon comparison, and categories emerge upon more comparison. And that is all there is to it” (p. 43). The researcher makes the connections necessary for initial theory generation.
Selective coding. The last stage of coding—selective coding—occurs when true theory generation takes place. Strauss and Corbin (1990) defined selective coding as “the process of selecting the core category, systematically relating it to other categories, validating those relationships, and filling in categories that need further refinement” (p. 116). This definition introduces a new concept, the core category (also called the central theme, the core variable or the basic social process [BSP] by Glaser). The core category is self-explanatory; it is the “central phenomenon around which all other categories are integrated” (p. 116). In this third phase of coding, the researcher aims to identify one of the previously coded categories (either open or axial) and determine whether and how the others revolve around it. As the researcher exposes the core category and illuminates the relationships the other categories have to this core, she or he establishes the basis for grounded theory (Babchuk, 1997; Creswell, 2002). Strauss (1987) listed the properties of the core category:

1. It must be central; that is, all other categories can be related to it.
2. It must appear frequently in the data. . . .
3. The explanation that evolves by relating the categories is logical and consistent. There is no forcing of data.
4. The name or phrase used to describe the indicator should be sufficiently abstract that it can be used to do research in other substantive areas. . . .
5. As the concept is refined analytically through integration with other concepts, the theory grows in depth and explanatory power.
6. The concept is able to explain variation as well as the main point made by the data; that is, when conditions vary the explanation holds. . . . (p. 36)

At this point the study is reassembled. The researcher uses all the data, including current literature in the area, to birth the emerging theory. New data are collected to fill in gaps, help clarify, and eventually verify this theory (theoretical sampling); however, this is not the final step in this methodology. The foundation of constant comparison means that as a theory (or a core category) emerges, the researcher compares it to the data; and new data collection takes place to test and shape the theory. Thus, the theory is modified or discarded if necessary, and the cycle continues. In the complete cycle all aspects of the theory are questioned—not only the core category but also why it was selected, not only the relationship of the core category to the theory but also its relationship with other categories. Only after saturation has occurred can the researcher claim completion; only after no new categories emerge and vie for dominance, only after all categories and relationships have been evaluated for centrality can a researcher claim theory grounded in the data. Glaser (1992) stressed that the researcher must “simply code and analyze categories and properties with theoretical codes which will emerge and generate their complex theory of a complex world” (p. 71) and “trust that emergence will occur and it does” (p. 4).

In chapter 4 the data has not only been presented as it occurred but the concurrent data analysis happening simultaneously has also been illuminated. As the data collection nears an end, the reader will also see that the analysis has completely run the cycle described above and a generated theory has emerged.
Rigor

Grounded theory methodology was founded on the principle of bringing the rigor of “good science” into studies of complex social situations. Although its founders referred to concepts such as objectivity, validity, and reliability, these ideas have been reworked for studies such as this one: “Terms such as credibility, transferability, dependability, and confirmability have replaced the usual positivistic criteria of internal and external validity, reliability, and objectivity” (Denzin & Lincoln, 1994, p. 14).

Qualitative researchers may not always precisely follow the good science view of rigor, but they must be “interpretively rigorous” (Lincoln & Guba, 2000, p. 179). Glaser and Strauss’ insistence upon the “rigor of systematic generation of theory” resounds today: “As a systematic process, grounded theory exhibits the rigor quantitative researchers like to see in an educational study” (Creswell, 2002, p. 447). One may be tempted to assume that if the method has been followed, rigor will automatically follow; however, the difficult questions of goodness are not as a consequence automatically answered. Many of these questions were boiled down to their essence in Lincoln and Guba’s (2000) discussion on the issue of validity: “Are these findings sufficiently authentic . . . that I may trust myself in acting on their implications?” (p. 178). Therein lies the key to rigor questions and the main problem Glaser and Strauss attempted to solve with grounded theory. The labels and constructs of the experimental method in the so-called hard sciences do not fit well in studies of social processes, but the idea of good science can transfer. Is the work good, is it authentic, was it pursued rigorously, is it reported fairly and completely, and many other questions have replaced constructs that
could only be superficially applied to this type of study (see Denzin & Lincoln, 1994; Lincoln & Guba, 2000, for a complete discussion of the new types of questions asked in qualitative research).

These issues have not after all been ignored in grounded theory methodology; indeed, they are ingrained in the entire process. Data saturation, another major tenet of grounded theory methodology, is an example of ingrained rigor. In terms of validity issues, saturation includes but goes beyond extended time in the field (Creswell, 2002). It entails a complete exhaustion of the possible data—the use of notes, literature in the area, memos, and all other data to achieve closure. The researcher should sense a feeling of completeness to the data and its analysis (Hutchinson, 1988); that is, “category development [reaches a point] at which no new properties, dimensions, or relationships emerge during analysis” (Strauss & Corbin, 1998, p. 143). The directive of saturation drives the study toward the rigorous scientific ideologies the originators attempted to obtain (or maintain).

Other validity issues evolve into issues of triangulation. Denzin and Lincoln (1994) stated, “[The] use of multiple methods, or triangulation, reflects an attempt to secure an in-depth understanding of the phenomenon in question. . . . Triangulation is not a tool or strategy of validation, but an alternative to validation” (p. 2). Multiple methods are a centerpiece of grounded theory methodology, the “slices of data from different sources” Glaser (1978, p. 438) wrote about. Thus verification and validation are visible “throughout the course of a research project” (Strauss & Corbin, 1994, p. 274) by
“build[ing] the triangulation process into ongoing data collection” (Huberman & Miles, 1994, p. 438).

Grounded theory methodology embraces other good science or rigorous measures. Generalizability or transferability is enhanced by “looking at multiple actors in multiple settings” (Huberman & Miles, 1994, p. 435). Fairness and honesty are keystones to theory building: “Theories are always traceable to the data that gave rise to them” (Strauss & Corbin, 1994, p. 278), and “validating one’s theory against the data completes its grounding” (Strauss & Corbin, 1990, p. 133). Objectivity is handled in a very honest and rigorous fashion:

Fortunately, over the years, researchers have learned that a state of complete objectivity is impossible and that in every piece of research—quantitative or qualitative—there is an element of subjectivity. What is important is to recognize that subjectivity is an issue and researchers should take appropriate measures to minimize its intrusion into their analysis. (Strauss & Corbin, 1998, p. 43)

In other words the researcher must look for methods that “control intrusion of bias into analysis while retaining sensitivity to what is being said in the data” (p. 43). Morse and Richards (2002) stated, “The goal of discovering theory from data sets high standards for the data, both in depth of detail and coverage of process” (p. 56). The methodology itself sets the rigor standard high.

Issues of rigor for this particular study have been discussed in the final section of chapter 4.

Limitations of the Study
All studies are limited to a degree, and this one was limited in several major ways: (a) limited context of the participants, (b) my own values, (c) limited experience with the methodology, and (d) differences in student perspective beyond my control.

Although I took an appropriate sample of the school’s population and the school is fairly representative of the area, the sample in no way covers every context possible. Of course, this is a limitation of almost every study. Thus, how generalizable will any of the results be? If the question is whether or not “this ‘case’ [is] representative of all cases,” then the answer is “probably not.” However, if one approaches this problem from the other side and asks, “What can I learn from this case (context) that might help in my understanding of_________?” (perhaps why some students dislike labs), then my conclusions may have value for the reader (see Strauss & Corbin, 1998, p. 285).

Another limitation has been clear from the introduction—that I, the researcher, have strong feelings on this subject. As a science teacher I have an almost engrained sense that laboratory activities must be valuable in spite of the research to date which suggests otherwise. This has had both a positive and a negative effect. On the positive side, my interest has provided the necessary drive not only to complete this study but also to complete it with the rigor grounded theory demands; but bias problems are inherent in these same strong values. The struggle to allow the data to reveal itself even if it ran counter to my own instincts or desires is a side effect of strong researcher feelings, yet I relied on the rigor of grounded theory itself and adherence to its methodology to combat the natural tendency to see what I wanted to see instead of what the data presented.
A third limitation was my lack of experience with grounded theory methodology. Multiple readings and hours of reflection can start one on the right path, but all the writers agree that the only way to understand the methodology fully is to put it into operation. This study was my first attempt at such a methodology.

The final limitation entailed factors beyond my control, for example, the assumption that all lab experiences are relatively the same for all the students sampled. Clearly, in a public school with different teachers with different priorities and teaching styles, this was not the case; furthermore, because this study focused on the student perspective, anything that affected that perspective was apparent in the data, but not all the effects may have been the result of the issues of the study. Although I used data saturation and other rigor issues described above to reduce these impacts, they could not be completely eliminated.

Also in this vein is the limitation imposed because I am an active science teacher at the study site. Approximately a quarter of the participants in this study would have been current or past students in my classes. I worked to eliminate my own influence as much as possible by having others administer the surveys and through application of rigorous procedures of grounded theory. However, it is still possible some of the data was influenced by the student/teacher dynamic. As I found on many limitation issues, the final data produced had a depth and candor which argues against this possible drawback.

The study had its limitations, but I strove to make it transparent. In a data poor but contextually complex area such as this, a final answer may not necessarily have emerged; nevertheless, I attempted to locate and place one piece of a complex puzzle.
CHAPTER 4

CONCURRENT DATA COLLECTION AND ANALYSIS

Introduction

In this chapter I have presented the data collected over the course of the study. Because one of the tenets of grounded theory involves the constant comparing of the body of data with itself (Glaser & Strauss, 1967, p. vii), data collection and data analysis have been interwoven (Strauss & Corbin, 1994, p. 273) in this chapter. In the first two sections I have focused on the two major student data sources: (a) the open-ended student survey, and (b) the student interviews. In the third section I have presented the emerging theory and data gathered using a faculty focus group for refinement and validation. As an aid to the reader, Figure 1 shows a summary of all the data sources used in this study and their relation to the concurrent analysis and eventual verification steps.
Figure 1. Data summary.
The Open-Ended Student Survey

*Formulating the Survey Using Field Observations*

Work on the survey (see Appendix A) commenced in the spring of 2007 with field observations of students working in laboratory settings. The objective of the research at this point was simply to gather a semblance of the student perspective in order to formulate an effective survey. Biases I had formed over 20 years of teaching had to be eliminated so I could narrow the focus of the study to the student’s perspective instead of my own. The three most pertinent field observations that challenged researcher biases to the point of modifying the student survey follow.

The most prevalent observation was an apparent disconnect between the teacher’s engagement with the laboratory experience and the student’s engagement. Some lab activities engaged very involved students with an apparently detached teacher, but more often, the opposite was true: The students did not seem nearly as enthusiastic with the experience as the teacher. As noted in a researcher memo, I had observed this phenomenon previously, but it was more prevalent than I thought: “This is obviously not the favorite activity of some... I’ve heard that in my classes but usually attribute it to the student” (Lambert, Researcher memo, May 11, 2007).

This observation led to the addition of a short multiple-choice section to the survey. In this section basic demographic data was gathered along with simple quantifiable data on students’ engagement with labs (What is your favorite/least favorite part of science class?) and their opinion of their teacher’s engagement with labs (Why do you think teachers make you do labs? What do you think is your teacher’s opinion of...
labs?). To help put the students’ answers in context, I included questions on how many labs a week were completed and how the students thought they were doing in the class; I also asked about their future science prospects.

A second important observation based on field notes led to the more student-friendly language on the survey. Whenever a student was asked anything about lab experiences—whether they thought labs were valuable, whether they learned anything from them, whether labs made science fun, whether labs made them like the course more, or many other “deep” questions—the students’ answers almost invariably opened with “Well, I don’t really like labs” or “I love labs.” In other words, no matter what the question asked about the experience, students’ typical responses started with a blanket statement on laboratory experiences in general. Accordingly, the survey was structured to match their thinking. The open-ended section of the survey was simply headed with a “Do you like labs?” question. Their answer to this question led to a section where they were asked to explain their answer in greater detail. As will be shown later in the discussion of results, the students themselves dissected their answers and delved into those deeper areas that I may have had to ask individually if not for this field observation. The depth of the students’ responses is an indication that this survey method revealed the student perspective without an imposed framework and helped remove some of the researcher bias as to which of these deeper questions was important to ask and which would be omitted from the survey. This observation encouraged me to alter the survey so I could measure these deeper ideas in a language the students used; this was accomplished without my having to ask each of the deeper questions individually. Doing
so may have either required more explanation of meaning or posed the danger of misunderstanding by the individual survey participant.

A third observation evolved into the final open-ended question on the survey: “What could make labs better?” Multiple observations of the same set of students often showed them highly engaged (participating and on task) in some labs and not in others. This perceptible observation indicated that the difference in engagement may not have been student based but instead based on the experience itself. In simpler terms it was not that some students always enjoyed labs and others always didn’t but that a large segment of students whose enjoyment and engagement with the lab experience was somehow based in the lab itself. Some they liked; some they didn’t. This led not only to the final question on the survey but also to the addition of a third option and section on the main open-ended question. I found it necessary to add a “sometimes” possibility to the question “Do you like labs?” With the addition of this third section, the survey was complete and ready for administration.

**Quantifiable Survey Results**

The survey was offered to every student at the high school taking any science course during the spring semester of 2006, and 665 completed surveys were returned. Of the almost 900 science course enrollees, the nearly 100 students who were registered for more than one science class at the time were asked to complete the survey only once. This resulted in a survey response rate of well over 80% (665 out of approximately 800), very satisfactory for this data source.
The multiple-choice section of the survey yielded many expected results (for a complete breakdown of frequencies see Appendix B). The data show that approximately one third of the survey results came from Grade 9 students with another third coming from Grade 10 students and the last third from a combination of Grade 11 and 12 students. This would be expected because the school requires 3 years of science. The data reflected the school’s internal demographic data as far as year in school, the number of science courses taken, and expected grade in the class. This suggests that the data derived from this survey were representative of the science student population at this particular high school.

Obviously, the most important piece of information was how the students answered the main question, “Do you like labs?” Teachers typically have a sense that students enjoy laboratory experiences, and that may be one reason we continue with them in the face of the lack of supporting data. This assumption was borne out in the data from this question. Fully 348 of the 665 responding students (52.3%) indicated they liked labs. Another 270 (40.6%) indicated they sometimes like labs, but only 40 (6%) noted they did not like labs. (On the remaining seven surveys the respondents failed to answer this question). Therefore, 618 out of 665 students, or almost 93%, signified they like labs at least some of the time.

Statistical analysis of the quantifiable data showed nothing that reached statistical significance. This result is to be expected as most of the data was demographic in nature and was used primarily as background for the study. However, examining this data showed several interesting trends, for example, the change in opinions of classroom
activities as the student progressed through grade levels. Although the students’ choice of teacher demonstration and student laboratory activities as their favorite classroom activity remained fairly constant through the grade levels (approximately 25% of the students listed them as their favorite activity), the students’ opinion of lectures and group work (other than lab work) changed. A comparison of Figures 2 and 3 illustrates how these two activities reversed in priority. A lecture never ranked high as a favorite classroom activity, but as the student progressed through the grades, group work was less favored and the more teacher-centered classroom lecture was more appreciated.

![Figure 2: Favorite activity](chart.png)
The same trend was apparent during the initial coding of the open-ended question to determine why some students liked labs; “freshmen are picking a lot of social reasons for yes [to the question did they like labs], older students picked more visual/understanding/variation reasons for yes” (Lambert, Researcher memo, July 5, 2007). These early data pieces remained throughout the data analysis. These two issues (social reasons vs. understanding reasons) gave rise to the idea that several themes may have been at work at once in a student’s perspective on laboratory activities. Although some of these may have been beyond the teachers control, some themes may be distilled from the data that teachers can influence and therefore give the overall experience more value and
impact. This idea truly unfolded in the analysis of the free response answers discussed later in this chapter.

Although the foregoing trend does not speak directly to the activity central to this project, laboratory activities, another interesting corollary emerged. Looking at Figure 4, one notes a small increase in lab activities being chosen as the least favorite classroom activity as students progress through their high school science classes. Because laboratory activities are typically performed with others, whatever decreased the desirability of group activities as the students aged may have also affected how they perceived labs.

This was the first indication of the connection between work in the laboratory and student group work. This recurring theme, although never prominent, cut across all demographic boundaries and was a factor consistently mentioned whenever students discussed these activities. Further investigation is needed to determine the factors responsible for these activities.

Figure 4. Lab as least favorite activity
trends and to determine whether the same factor affected students’ perceptions of both group work and labs or whether separate factors were at work for each activity.

Another interesting trend involved teacher demonstrations, which bridge the gap between the teacher-directed lecture and the (usually) student-directed lab. The manipulation of actual “things” lends itself to what the standards (National Research Council, 1996) identified as a “hands-on” activity; however, the students themselves never actually get their hands on the materials in a teacher demonstration. The teacher usually performs a well-rehearsed version of an activity with little chance for failure and with concurrent explanation so the point is clearly seen.

The trend itself manifested itself in the answers to several questions that centered on how a student answered the last question: “Do you like labs?” If students answered that they liked labs,” their least favorite activity was teacher lecture (72.2% vs. 27.5% if they didn’t like labs or 56.6% if they sometimes liked labs). Among those who answered that they didn’t like labs, their favorite activity was teacher demonstration (33.3%). Those who took the third choice that sometimes they liked labs showed a cross between the two choices above. Their least favorite activity was lecture (56.6%), and their favorite activity was teacher demonstration (31.4%). This trend provided insight into the student perspective; involved were questions about who is controlling the action, is the student an active or passive participant, what are the possibilities of failure, and will I (as a student) “get” the point. This brings individual preferences among students and how they affect their perspective into the data analysis.
These are questions further illuminated in the later analysis of the open-ended responses, but the beginnings of this stream of analysis became apparent early in the research. The data have shown separate issues for various students. The analysis at this point has merely yielded the suggestion that a singular student perspective on laboratory experiences is not likely to appear. This implication arose in the argument for qualitative methods in the beginning of this paper. If the student perspective could be simplified to a single “answer,” quantitative measurements would suffice. Qualitative methodology implies more to be found and multiple perspectives to be observed, yet this suggestion also implies, on a more pragmatic level, that improvement in the overall experience will not come from one area; it will involve different needs for different activities and different students. This is a much more daunting task than past research has suggested.

Earlier researchers have criticized some types of lab activities, for example, cookbook labs or verification labs, because of the perceived lack of inquiry (Herron & Nurrenbern, 1999; McComas, 2005; Montes & Rockley, 2002; National Research Council, 2002; Tobin, Tippins, & Gallard, 1994). These data have suggested that there may be a place for these activities at some point for some students. Two early entries in the researcher memos included observations from the student data that “cookbook labs may have value” and “maybe they want to understand the concept more . . . then verification labs ARE ok” (Lambert, researcher memo, June 11, 2007). This revelation may seem simplistic and obvious, but the current work in most high school science arenas reflects the trend toward less verification. Note the conflict generated between the works mentioned above and the emerging student data: “This is not what we are hearing
in our graduate work and research” (Lambert, researcher memo, June 11, 2007). In the words of a student teacher, “Every lab, actually every lesson has to be guided inquiry.” The literature correctly pointed out that inquiry is the primary component of laboratory experiences, and it should be noted, inquiry and verification are not mutually exclusive; however, the student perspective data have revealed a trend away from the singular answer of more inquiry. This analysis merely proposed that different students may benefit from a variety of laboratory formats, not just inquiry but also perhaps from some verification and other style experiences.

According to students the reasons teachers require them to engage in laboratory activities (Figure 5) reflect some of the differences in student preferences. The “discovery of new ideas” (intended to match inquiry-type labs) was marked very high (31%), but the response intended to match verification-type labs was the most frequent reply.

![Figure 5. Why do teachers make you do labs?](chartgeometry)

This question directly asked why students thought teachers made them do labs, yet their responses very likely indicated what they themselves thought the lab experiences were
trying to accomplish. Overall 38.2% of all students thought that the primary purpose of a lab experiences was to verify the concepts covered in class. Even students who indicated they liked every lab every time chose verification as the primary purpose (35%) for the experience. At this point in the data and its analysis, leaping ahead is tempting; yet all that can be noted is the student interest in multiple styles of laboratory experiences and how these may encompass experiences not currently favored in the literature. Using a variety of techniques in the classroom to meet individual students’ needs is a foundation of good practice that deserves further exploration.

A final piece of the student perspective mined from the multiple-choice section of the survey was the relationship between what a student thinks about labs and what that student believes her or his teacher thinks about labs. Most students believe their teachers personally enjoy laboratory experiences (81.3%). A more negative choice was that teachers made students engage in the lab experience because “it’s something we [science teachers] do.” Among students who indicated they didn’t like labs in general, this choice was selected 27.5% of the time in contrast with only 12.1% of the time among those who indicated that they liked labs. Predictably, those who indicated they sometimes like labs fell between these two extremes, choosing this response 20.4% of the time. At this point it was difficult to ascertain whether a connection existed between what a teacher thinks about laboratory experiences and whether or not their students like these experiences. It is also possible this trend is merely a reflection of the value placed on these activities by the students themselves; for example, if the student didn’t like labs, he
or she recorded a negative reason for being subjected to the experience. This possible
connection is another area that merits further research and analysis.

Open-Ended Survey Results

Format of the open-ended response section. A surprising outcome often noted in
the researcher memos was the richness of the survey data. Originally intended only to
inform the questioning during the interview process, the depth, variety, and candor of the
student responses to the open-ended questions elevated this data source to prominence.
This depth of response provided a very data-rich picture of the student perspective
required by research question at the center of this project.

After the students answered the last multiple-choice question (Do you like labs?),
they were directed to a section of free-response questions geared toward their answer
choice (see Appendix A). The questions follow: (a) Why do you like/dislike/sometimes
like labs? (b) Give me an example of a lab you liked/disliked and tell why; and (c) (for
those who answered they liked labs) Is there anything you don’t like about labs; (for
those who answered they didn’t like labs) Is there anything you like about labs. This was
followed by the question “What could make labs better?” directed to all students
regardless of whether they indicated they liked labs or not.

The responses were first sorted by students’ choice: liking labs, disliking labs, or
sometimes liking labs. The resulting data were then analyzed by open coding (Glaser,
1978, p. 57; Strauss & Corbin, 1998, p.101), using common responses to create these
codes. The coded data was also then combined to achieve a total response section.
Open coding of the responses of those who liked labs. Of the 665 completed surveys, 348 (52.3%) of the respondents indicated they liked labs in the multiple-choice section. All but 7 of these 348 survey respondents provided input in the free-response section. Of these surveys, open coding of the free responses identified 729 unique statements indicating reasons they liked labs, 264 statements indicating reasons they disliked labs, and 241 suggestions to make labs better. The coding of the most repeated statements is summarized in Tables 1–3.

Table 1

Coding of Responses: Why Those Who Liked Labs Liked Them

<table>
<thead>
<tr>
<th>Number of responses</th>
<th>Reasons that students who liked labs liked them</th>
</tr>
</thead>
<tbody>
<tr>
<td>136</td>
<td>It’s fun/cool/exciting</td>
</tr>
<tr>
<td>99</td>
<td>It explains lesson/helps me understand</td>
</tr>
<tr>
<td>96</td>
<td>It’s hands on</td>
</tr>
<tr>
<td>64</td>
<td>It’s visual/seeing the way things are</td>
</tr>
<tr>
<td>44</td>
<td>It’s group work</td>
</tr>
<tr>
<td>41</td>
<td>It’s interesting</td>
</tr>
<tr>
<td>34</td>
<td>It’s an application of learning/brings lesson to life/real world</td>
</tr>
<tr>
<td>30</td>
<td>I’m up and moving</td>
</tr>
<tr>
<td>25</td>
<td>It’s not lecture</td>
</tr>
<tr>
<td>25</td>
<td>It’s self-discovery [find something on your own]</td>
</tr>
<tr>
<td>23</td>
<td>It’s easy to understand/learn</td>
</tr>
<tr>
<td>22</td>
<td>It’s interactive/gets me involved/engaging</td>
</tr>
</tbody>
</table>
Table 2

*Coding of Responses: What Those Who Liked Labs Didn’t Like About Them*

<table>
<thead>
<tr>
<th>Number of responses</th>
<th>Reasons that students who liked labs didn’t like them</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>Lab reports/writing/questions/packets</td>
</tr>
<tr>
<td>21</td>
<td>Rushed/not enough time</td>
</tr>
<tr>
<td>19</td>
<td>Boring labs</td>
</tr>
<tr>
<td>17</td>
<td>Confusing directions</td>
</tr>
<tr>
<td>13</td>
<td>Unnecessary if you already understand/pointless/repetitive</td>
</tr>
<tr>
<td>10</td>
<td>Partner doesn’t work/bad partner</td>
</tr>
</tbody>
</table>

Table 3

*Coding of Responses: Suggestions to Improve Labs Among Those Who Liked Them*

<table>
<thead>
<tr>
<th>Number of responses</th>
<th>Suggestions for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>Have more of them</td>
</tr>
<tr>
<td>21</td>
<td>Use fewer questions at the end</td>
</tr>
<tr>
<td>15</td>
<td>Have more explanation/discussion</td>
</tr>
<tr>
<td>14</td>
<td>More time</td>
</tr>
<tr>
<td>12</td>
<td>Even more hands on</td>
</tr>
<tr>
<td>10</td>
<td>Do less boring labs</td>
</tr>
<tr>
<td>10</td>
<td>Have less confusing directions</td>
</tr>
</tbody>
</table>
The analysis of this open coding has been discussed after the presentation of the coding of the other two sections.

*Open coding of responses of those who disliked labs.* Of the 665 responses only 40 (6%) respondents indicated they disliked labs. Open coding of these responses found 89 unique statements containing reasons for the dislike, 21 statements of specific aspects these respondents disliked about labs, and 39 suggestions for lab improvement. The most common responses are summarized in Tables 4 through 6.

Table 4

*Coding of Responses: Why Those Who Disliked Labs Disliked Them*

<table>
<thead>
<tr>
<th>Number of responses</th>
<th>Reasons that students who disliked labs disliked them</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Doesn’t help me learn the concept</td>
</tr>
<tr>
<td>11</td>
<td>Waste of time</td>
</tr>
<tr>
<td>11</td>
<td>Boring</td>
</tr>
<tr>
<td>9</td>
<td>I don’t get the idea/understand</td>
</tr>
<tr>
<td>5</td>
<td>Unclear direction</td>
</tr>
<tr>
<td>5</td>
<td>Not enough time/too long</td>
</tr>
</tbody>
</table>
Table 5

*Coding of Responses: What Those Who Disliked Labs Liked About Them*

<table>
<thead>
<tr>
<th>Number of responses</th>
<th>Reasons that students who disliked labs liked them</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Fun/cool/exciting</td>
</tr>
<tr>
<td>3</td>
<td>Working with a partner</td>
</tr>
<tr>
<td>3</td>
<td>When it helps me learn the concept</td>
</tr>
</tbody>
</table>

Table 6

*Coding of Responses: Suggestions to Improve Labs Among Those Who Disliked Them*

<table>
<thead>
<tr>
<th>Number of responses</th>
<th>Suggestions for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>More explanation of how lab applies</td>
</tr>
<tr>
<td>8</td>
<td>Clearer directions</td>
</tr>
<tr>
<td>4</td>
<td>Make them simpler</td>
</tr>
<tr>
<td>4</td>
<td>More interesting</td>
</tr>
</tbody>
</table>

Open coding of those who sometimes liked labs. The second most common reply to the question whether or not student liked laboratory activities was “sometimes.” This answer occurred in 270 of the 665 replies (40.6%). Open coding of these responses showed 207 responses on what they liked about labs, 345 responses on what they didn’t like, and 308 suggestions for improvement. The most common replies are presented in Tables 7 through 9.
### Table 7

**Coding of Responses: Why Those Who Sometimes Liked Labs Liked Them**

<table>
<thead>
<tr>
<th>Number of responses</th>
<th>Reasons that students who sometimes liked labs liked them</th>
</tr>
</thead>
<tbody>
<tr>
<td>69</td>
<td>Fun/cool/exciting</td>
</tr>
<tr>
<td>54</td>
<td>It’s interesting/interested in topic</td>
</tr>
<tr>
<td>21</td>
<td>It explains lesson/ helps me understand</td>
</tr>
<tr>
<td>14</td>
<td>Easy to understand/learn</td>
</tr>
<tr>
<td>8</td>
<td>It’s an application of learning/ brings lesson to life/real world</td>
</tr>
<tr>
<td>8</td>
<td>It’s hands on</td>
</tr>
<tr>
<td>7</td>
<td>I like unexpected outcomes</td>
</tr>
<tr>
<td>7</td>
<td>It’s interactive/gets me involved/engaging</td>
</tr>
</tbody>
</table>
Table 8

_Coding of Responses: What Those Who Sometimes Liked Labs Disliked About Them_

<table>
<thead>
<tr>
<th>Number of responses</th>
<th>Reasons that students who sometimes liked labs disliked them</th>
</tr>
</thead>
<tbody>
<tr>
<td>82</td>
<td>Boring labs</td>
</tr>
<tr>
<td>56</td>
<td>Unnecessary if you already understand/pointless/repetitiveness</td>
</tr>
<tr>
<td>41</td>
<td>Sometimes I don't understand what I'm doing/supposed to learn</td>
</tr>
<tr>
<td>26</td>
<td>I’m not interested in the topic</td>
</tr>
<tr>
<td>14</td>
<td>Rushed/not enough time</td>
</tr>
<tr>
<td>17</td>
<td>Lab reports/writing/questions/packets</td>
</tr>
<tr>
<td>12</td>
<td>Too long and drawn out</td>
</tr>
<tr>
<td>11</td>
<td>Confusing directions</td>
</tr>
</tbody>
</table>
Table 9

Coding of Responses: Suggestions to Improve Labs Among Those Who Sometimes Liked Labs

<table>
<thead>
<tr>
<th>Number of responses</th>
<th>Suggestions for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>More explanation/discussion</td>
</tr>
<tr>
<td>39</td>
<td>More fun/cool/entertaining</td>
</tr>
<tr>
<td>25</td>
<td>Less questions/math/graphing</td>
</tr>
<tr>
<td>20</td>
<td>More time</td>
</tr>
<tr>
<td>20</td>
<td>Less confusing directions</td>
</tr>
<tr>
<td>19</td>
<td>More hands on</td>
</tr>
<tr>
<td>17</td>
<td>Even more interactive/more stuff to do</td>
</tr>
<tr>
<td>12</td>
<td>Students pick topics/pick student relevant topics</td>
</tr>
</tbody>
</table>

Recoding and combining of all responses to gain a total picture. One final look at the raw data required a representation of the overall response. This necessitated not only the combining of the previous data but also some recoding to simplify the results. The data represented in Tables 10 through 12 embody the most common responses in the open-ended section in all 665 surveys.
### Coding of Responses: Why Students Liked Labs

<table>
<thead>
<tr>
<th>Number of responses</th>
<th>Reasons that students liked labs</th>
</tr>
</thead>
<tbody>
<tr>
<td>210</td>
<td>It’s fun/cool/exciting</td>
</tr>
<tr>
<td>123</td>
<td>It explains lesson/helps me understand</td>
</tr>
<tr>
<td>107</td>
<td>It’s hands on</td>
</tr>
<tr>
<td>95</td>
<td>It’s interesting/interested in topic</td>
</tr>
<tr>
<td>69</td>
<td>It’s visual/seeing way things are</td>
</tr>
<tr>
<td>50</td>
<td>It’s not lecture/ nontraditional</td>
</tr>
<tr>
<td>49</td>
<td>Group work/ get to be with friends</td>
</tr>
<tr>
<td>42</td>
<td>It’s an application of learning/ brings lesson to life/real world</td>
</tr>
<tr>
<td>37</td>
<td>It’s easy to understand/learn</td>
</tr>
<tr>
<td>33</td>
<td>Gets me up and moving</td>
</tr>
<tr>
<td>29</td>
<td>It’s interactive/gets me involved/engaging</td>
</tr>
<tr>
<td>27</td>
<td>It’s self-discovery</td>
</tr>
</tbody>
</table>
Table 11

*Coding of Responses: What Students Disliked About Labs*

<table>
<thead>
<tr>
<th>Number of responses</th>
<th>Reasons that students disliked labs</th>
</tr>
</thead>
<tbody>
<tr>
<td>114</td>
<td>Boring labs</td>
</tr>
<tr>
<td>99</td>
<td>Lab reports/writing/questions/packets</td>
</tr>
<tr>
<td>80</td>
<td>Unnecessary if you already understand/pointless/repetitive</td>
</tr>
<tr>
<td>69</td>
<td>Sometimes I don't understand what I'm doing/ supposed to learn</td>
</tr>
<tr>
<td>55</td>
<td>Not enough time/ too long</td>
</tr>
<tr>
<td>49</td>
<td>Complicated/complicated or confusing directions</td>
</tr>
<tr>
<td>32</td>
<td>Issues with being in group work</td>
</tr>
<tr>
<td>26</td>
<td>I'm not interested in the topic</td>
</tr>
</tbody>
</table>
Table 12

*Coding of Responses: Suggestions To Improve Labs By All Students*

<table>
<thead>
<tr>
<th>Number of responses</th>
<th>Suggestions for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>Give more explanation/discussion</td>
</tr>
<tr>
<td>49</td>
<td>Make them more hands on/interactive</td>
</tr>
<tr>
<td>49</td>
<td>Have fewer questions/less math, graphing</td>
</tr>
<tr>
<td>49</td>
<td>Make them more fun/cool/entertaining</td>
</tr>
<tr>
<td>44</td>
<td>Change the number of them (37 said more, 7 said less)</td>
</tr>
<tr>
<td>40</td>
<td>Make the directions less confusing</td>
</tr>
<tr>
<td>39</td>
<td>More time</td>
</tr>
<tr>
<td>24</td>
<td>Make them less boring/fewer busy-work labs</td>
</tr>
</tbody>
</table>

*Concurrent data analysis of the open-ended responses.* As the coding of the data unfolded, certain repeated themes emerged and formed the foundation of the analysis. As coding of individual comments progressed, they fell into broader categories, which constituted the early axial coding detailed above as the second stage of grounded theory analysis (see Strauss & Corbin, 1990, p. 97).

Many of the surveys yielded predictable remarks. Numerous students—regardless of age and whether or not they liked or disliked lab experiences—mentioned how much fun or cool or exciting some of them can be. As a science teacher I often hear such comments, and this notion was one of the unmeasured positive aspects of laboratory experiences that prompted this study as noted in the introduction. Student responses
varied from lengthy explanations of labs they liked to the simple expressions, such as “labs are fun” and “labs are cool,” to the unusual: “They get rid of the drone of the everyday.” Moreover, common among the responses was the idea of interest. Students who indicated they liked labs often mentioned that the experience was interesting or that the topic interested them. One student said, “They help me discover a concept of science without hearing the teacher lecture on about it. The labs keep me interested and wanting to learn more.” By contrast, students who replied that they didn’t like labs often mentioned that the labs were “boring,” “too long and drawn out,” or that they lacked interest in the topic. Related replies indicated that the work often seemed like busy work: “Right now everyone pretty much sees them as time fillers”; furthermore, some students suggested “fewer labs simply meant to keep students busy so that teachers can relax.”

Once these comments were coded, I grouped them loosely under the category of affective issues (Bloom et al., 1956; Krathwohl et al., 1956). The affective domain focuses on how students deal with things emotionally and includes feelings, appreciation, enthusiasms, motivations, and attitudes (Krathwohl, Bloom, & Masia, 1973). With well over half of the students mentioning something resembling the affective theme (416 individual phrases in 665 surveys), this is apparently an important piece to the puzzle that constitutes the student perspective on laboratory experiences. How important is this piece? Is it as important as cognitive gains as suggested by Shulman and Tamir (1973)? These are important questions but beyond the scope of this study. (For an in-depth discussion of the affective vs. the cognitive as well as how researchers have shifted focus to the cognitive, and more specifically, conceptual change, see Hofstein & Lunetta,
Because the purpose of this study was to translate the student perspective on laboratory experiences for science educators, one theme that cannot be ignored is the presence of affective issues in a complete discussion of these experiences. A senior summarized high school science labs and made suggestions for future labs: “There should be some ‘wow’ factor. When we did things as kids in science there was always a ‘Wow, that’s cool.’ That shouldn’t end in high school.”

Other data grouped themselves in a category labeled “learning goals,” and an interesting dichotomy appeared. A large number of students mentioned they liked labs because they help explain the concept they were learning or that they represent an application of that learning. One student said, “[A lab] brings the idea home; [it’s] a good physical representation of a concept, and [it] forces people to apply what they’ve learned (always good).” Another liked labs “because [they help] to click in my head.” A senior succinctly stated, “Tell me and I’ll forget, show me and I’ll remember, involve me and I’ll understand.”

By contrast one of the top reasons that students disliked labs was that they didn’t understand what they were supposed to learn or “get” out of the experience. One said, “I haven’t enjoyed labs in science since about fifth grade. If feel like I don’t learn anything, and they are a waste of time. Often, the concepts you are seeing played out are not well explained by the teacher.”

Although representing ostensibly opposing views, these data include a common theme as well as a nascent suggestion for science educators. At least one goal of laboratory activities is to facilitate student learning, and the students themselves notably
asked to understand exactly what that learning goal is. If students gain this understanding, perhaps many of those who expressed negative views about labs would be convinced otherwise if the lab experiences helped them understand concepts taught in class. Students suggested that “teachers should really explain the subject that way your not being frustrated while your trying to do the lab” and “make them easier to follow, also make it clear as to what this is teaching us and why it’s important.” (Students’ comments have been reproduced as written.) This linkage between the learning goals of the teacher and student understanding of the laboratory experience was reinforced by the data.

A third category was also derived from the coding of the data, this even more under the teacher’s direct control—the format of the laboratory experience itself. For this study format of the laboratory experience denotes all aspects involved with the actual performance of the experience. Examples of format items include the following: the directions given, the type of activity, the amount of work expected during a class period, the written work associated with the lab, the equipment used in the lab, and other elements under the teacher’s control that direct how the laboratory experience happens. Most of the feedback in this area was negative. The only common positive response in this area was that labs did not involve lecture, a classroom activity typically regarded as unpleasant. One student said about the lab experience: “We actually pay attention, it’s interactive, we don’t have to listen to lectures.”

Negative comments and suggestions were plentiful in this important area. A large number of the format comments focused on understanding the directions for the lab. One student said, “I never understand what to do (even with directions), I don’t learn anything
from [the lab].” Some student remarks focused on the actual wording of the lab:

“Sometimes they use more complicated language than we know”; but most focused on
the teacher’s explanation of the directions both beforehand and even during the lab: “The
teacher could get more involved and ask questions as we look at the lab and answer the
questions as a class, so we do it right and are on the same page.” Understanding was a
word used often in the previous section as students struggled to understand the learning
goal of the laboratory experience. These comments along with the comments directed at
understanding the directions made “not understanding” the most common complaint
about labs and “more explanation” the most common suggestion to make these
experiences better. In my researcher memos I noted, “Why this big desire to ‘understand’
the lab?” (Lambert, Researcher memo, November 27, 2007) and “Understand: is it about
directions or the point of the lab — probably both” (Lambert, Researcher memo, January
03, 2008). I contemplated grouping all comments and suggestions about understanding
together and creating a core category; however, I recognized a distinct difference
between the desire to understand the learning goal of the lab on one hand and the desire
to understand the directions for executing it on the other. How one solves these problems
requires various actions by the teacher. Because “I don’t understand” is an oft-heard
complaint from students, the teacher must determine precisely what they fail to
understand. Likewise, I needed to determine what students failed to understand in order
to keep these two concepts distinct.

Another common format issue entailed the usefulness of the lab itself. Many
students complained that some labs are boring. Although educators should keep interest
value in the back of their minds and strive to keep their labs as exciting as possible, many of these comments reflect individual preference. Educators will never be able to please everyone; however, some of these comments derive from deeper issues, and they merit examination. Many comments addressed format issues; for example, “some of them [labs] are unnecessary if the class already understands the concept” and “in most cases the general idea or concept doesn’t take long to understand.” The suggestion “not [to do] labs in which you can answer the questions without even doing the lab” also emerged. In these comments “boring” or “unnecessary” do not spring from opinion but instead from an assessment of the decision to invest class time in the experience. I noted in my researcher memos: “a lot of older students [are] picking out useless labs” and “a lot of ‘don’t waste my time with busy work’” (Lambert, Researcher memo, July 6, 2007). Such comments may reflect more individual preferences than the sentiments of entire classes, but whether or not to do an activity that is a personal favorite of the teacher is a question educators must pursue further; this issue has been discussed below.

A third comment that students frequently made with regard to format referred to the time allotted for the laboratory experience. Class periods at this particular high school were 48 minutes long, and in the view of many, the time allotted was insufficient to complete the lab. With 55 individual comments noting insufficient time and 39 suggestions for more time, the following student comment summarized the general attitude: “Plain and simple, some people need more time.” I captured another issue that was expected in the following: “Early impression: many more picking more time (what I thought all would say)” (Lambert, Researcher memo, July 10, 2007). Science educators
will not likely be able to adjust the length of the day or the class period; thus the only
way to eliminate the students’ complaint is to reformat the labs to fit the existing
structure. Doing so is imperative because much of what students found objectionable
about labs was generated by a lack of time. I noted, “There is an overwhelming sense of
dislike of labs they didn’t get to finish” (Lambert, Researcher memo, July 10, 2007).

The last frequently mentioned format issue regarded the lab report, including
questions at the end of the lab, calculations to be completed, a worksheet to be filled out,
or other work in addition to the common definition of a lab report. Expecting this issue to
emerge, I received many comments similar to the one expressed in the following line of
thinking: “A lot of paperwork [is] included that distracts you from the actual lab.”
Unexpectedly, however, many students voiced a dislike for this extra work but were able
to see that it was necessary. One student noted that he or she disliked “the inevitable
questionare [sic] at the end, but it’s a necessary evil.” Another student echoed a distaste
for “the calculations,” but when suggesting improvements to the laboratory experience he
or she noted, “I think a lab can’t be changed because if you take away calculations and
writing, what do you gain from a lab?” This opinion came from students with more
laboratory experience: “Older [students are] saying they don’t like reports but understand
they are needed” (Lambert, Researcher memo, July 2, 2007). Although these comments
were often mentioned, the issue needs little work or change from science educators.
Given the desire of students to “get the point of the lab” noted above, teachers can
legitimately take the stand that this extra work may be viewed negatively, but most
students (and teachers) know it is necessary.
Coding produced three categories that describe the student perspective. Comments including words such as *like* or *dislike* and *cool* or *boring* were coded into the affective domain. Other comments focused on the learning goals of the laboratory experience, and still others focused on format issues of the experience itself. A few student comments clearly summarized the most common issues:

I usually screw them up; they’re very complicated and time consuming; I usually don’t get any main idea out of them.

I think sometimes labs are pointless, and the teachers know it but do them anyway. . . . Labs should be something kids can relate to but work hard at the same time. To make labs better, I think they should be fun and the point of the lab should be more apparent.

*Visualization of and connections among the three categories.* The evolution of the data into three categories—affective issues, learning goal issues, and format issues—necessitated graphic representation (Strauss & Corbin, 1990) of the analysis to this point. As noted in the discussion of grounded theory methodology, once axial coding has been used to condense the data into categories (Hutchinson, 1988), a chart or diagram is helpful to extend the data analysis (Huberman & Miles, 1994). Although three distinct categories polarized the data, some data overlapped more than one area and some overlapped all three; for example, a student suggested that labs should be more interactive. Making the lab more interactive is a format issue, but the desire to have more interaction is an affect issue. Another example occurs in a comment that a student likes a lab because “it is easy to get.” The design (directions, etc.) that made the experience
“easy to get” would be a format issue; however, the student’s getting the point of the lab is a learning goal issue. Visualization could be made clearest with a Venn diagram. After recategorizing the data into these three categories, little difference was apparent in comments based on how the student answered the question on whether or not they liked labs. What they liked, disliked, and suggested for labs did not change based on whether the individual overall liked labs or not: The remarks remained consistent. Thus the most important visualizations are the ones that include all students. Figures 6 through 8 present the three themes, including any existing overlap. Figure 6 indicates what students liked about labs, Figure 7 what they commonly disliked, and Figure 8 their suggestions for improvement. Appendix C contains Figures 9 through 17, which categorize and visualize the data based on how the student answered whether or not they liked labs.
Figure 6. What students liked about labs

(Note: The number of times the comment presented in the data is noted in parenthesis.)
Figure 7. What students disliked about labs

(Note: The number of times the comment presented in the data is noted in parenthesis.)
Figure 8. Student suggestions for improvement

(Note: The number of times the comment presented in the data is noted in parenthesis.)
These diagrams help focus attention on three main areas instead of on the numerous and diverse comments from the students. Looking at these figures allows patterns to emerge; for example, Figure 6 shows that the majority of the positive comments were focused on the side of the diagram with issues of the affective and learning goal. Two freshmen commented: “It makes science better and helps me understand the topic better,” and “For me it’s the best way to understand the concepts and is fun as well.” Noting this pattern while maintaining an awareness of the high percentage of students who indicated that they like labs (93%), I clearly saw that positive affect reasons, especially enjoyment and interest, were major components of the student perspective. Furthermore, most students understood that actual educational goals underlay these experiences. An interesting question that revealed itself many times in this study entailed whether the accomplishment of the learning goal to help students understand the lesson influenced those affective components like enjoyment. In other words, because the notion that labs are fun or cool was cited 210 times and the notion that labs help explain the lesson was mentioned 123 times, does a connection exist between these top two reasons that students liked labs?

Figure 7 shows another facet of the issue: that most of the suggestions given were on the format side. Students had real, generally well-conceived suggestions for improvement of these experiences. Very few comments lacked reflection and simply noted approval, dismissal, a liking for, or dislike of laboratory experiences. Students knew what they liked and disliked. Although a few noted that “hands-on just isn’t my
thing,” most believed these experiences can be positive, and they believed they know what can make them better.

Figure 6 places both of the previous points into a pragmatic context, from which an interesting dichotomy emerged. Although Figure 5 reveals that the role of labs in helping students understand the concept was a major aspect students liked about labs, nearly the opposite occurs in Figure 6, where the negative comment mentioned most frequently made about the learning goal was that students did not understand the point of the experience. This led to many comments on the format side, which mirrored the suggestions shown in Figure 7. Again the link appears between understanding the experience and whether or not the experience was viewed positively. At the same time many suggestions point toward increased student understanding.

Looking at these diagrams reveals many interesting overlaps and patterns worth noting and discussing. Of course, the placement of data was a product of the concurrent data analysis ongoing in this study and is open to reinterpretation and a different categorization by others. To increase the credibility of the coding, the data was given to two outside readers, who verified the feasibility of these chosen categories; the discussion of this verification has been included in the last section of this chapter. The choice of pattern and overlap discussed above foreshadowed the next stage of data analysis—identification of a core category.

If a superficial look at the student perspective on laboratory experiences is all that is required, then the diagrams above would suffice in painting that picture; however, doing so would leave the data in a vacuum without context or meaning. Listing of all the
students’ comments would provide data, but doing so is no different from experienced teachers listing every comment they have ever heard about their teaching but failing to reflect on them. Placing these comments into categories helped focus attention and eliminated time and energy spent on outlying data. I hoped that “the categories developed match the realities of those interviewed” (Tuettemann, 2003, p.10), but this important step in the data analysis was insufficient to complete the picture. In the practical work of education many variables exist in every decision the teacher makes. Knowledge of all the important variables (or in this study, the three categories) is important, but when reflection for improvement is the goal, the modern educational setting often allows the educator to focus only on the most important, or core, variable. Glaser (1978, pp. 94–95) described this variable or category as a central idea that reoccurs frequently, takes more time to saturate, makes connections with other categories easily, and leads to formal theory not dead ends. Strauss and Corbin (1990) simply described it as a story line around which everything else is draped. Scott (2004) used categories as I have in this study and defined the core category as “the central phenomenon about which all other major and minor categories relate” (p. 120).

*Student understanding as a core category.* The temptation when looking for a core category is simply to look at where all three parts of the Venn diagrams overlap, yet at this intersection are located only student comments that contain all elements of all three areas. All three areas contained in one comment does not necessarily make it core. A better question follows: “Does any concept cross all the areas, something that every area is tied to yet may not be specifically vocalized in the student comments?”
Straus and Corbin (1990) suggested a fairly rigid methodology to locate this core idea. Glaser’s (1978) open and flexible approach is more amenable to delving into the data and allowing the core to emerge automatically as long as the researcher is sensitive to it. In this study no strict methodology was necessary. The core category appeared at the outset of the study and remained prominent throughout data collection and analysis in Glaserian fashion.

Charmaz (2006) noted the value of writing researcher memos because they encourage the researcher “to analyze . . . data early in the research process” (p. 72). The first three researcher memos I wrote were “students wanted to understand the labs more” followed by “is that understanding the directions” and “maybe they want to understand the concept more” (Lambert, Researcher memo, June 11, 2007). Thus, relatively early in the study and during concurrent data analysis, the word understanding appeared repeatedly. It is the common thread that answers and ties together many of the questions and comments already mentioned in this study to this point. Looking back to the comments made by students who indicated that they liked labs, I see that many directly addressed the way the labs helped them understand and were easy to understand. Many of the comments from the overlapping areas took little imagination to see they also relate to student understanding. For example, the 69 comments made regarding labs as a visual way to learn actually address a unique way to understand the concept. Likewise, looking at the comments made by those who disliked labs will show many comments (126) directly revealed a lack of understanding the point or the directions of the laboratory experience, but again many of the others may have been directly related to this idea. The
comments that labs were “boring” or “pointless” or “busy work” may have derived from these students’ lack of understanding the point or what the teacher was trying to accomplish with the experience. When the students made suggestions for labs, more explanation and discussion were the most frequent responses. Two other common replies—“less confusing directions” and “less boring/busy work”—related to this core category as well. Even all the comments about lack of sufficient time, which were categorized as format comments, could apply to this idea. Of course, sometimes students actually need more time to do the physical work of the laboratory experience; however, most often the time constraints of the high school schedule permit no time for student–student and student–teacher discussion about the experience, when much of the “understanding” takes place. In constructivist terms it is the time when students use the experience to scaffold from where they were to new areas of learning. More has been discussed on this point in the next chapter.

By the end of the analysis of the open-ended surveys, the core category of students’ desire to understand the experience better had emerged. The student perspective on laboratory experiences reveals many facets and niches based on individualization and experience; however, this one recurring theme crossed the boundaries of age, level in school, gender, and even whether the student viewed lab experiences as positive or negative. With this core category in place, the next phase of the study—individual student interviews—came into a clearer focus. Serving as a check on the veracity of the data collected to this point, the interviews focused on exploring and clarifying the student perspective on understanding laboratory experiences.
Individual Student Interviews

The individual student interviews served to further define, elaborate, and often repeat this core category, “Bad labs are you either (a) don’t understand the material or (b) [pause] I don’t know” (Interview 4).

The interview process followed the grounded theory practice of theoretical sampling (see chapter 3, sampling procedures), which is “sampling on the basis of concepts that have proven theoretical relevance to the evolving theory” (Strauss & Corbin, 1990, p. 176); more simply stated, “the purpose of theoretical sampling is to obtain data to help [the researcher] explicate . . . categories” (Charmaz, 2006, p. 100). Although the survey provides a broad picture of the student perspective on laboratory experiences, theoretical sampling during the interview process allows a focus on the three identified categories, and more specifically, questioning on the core concept of “understanding” (Tuettemann, 2003). Appendix D includes the interview outline used for student interviews.

The 12 formal interviews opened with a brief reminder of the survey followed by probing interviewees’ perspectives on labs. As discussed below, the responses mirrored the comments and categories of the open-ended surveys. This general questioning was followed with the specific question—“I’m hearing a lot about students wanting to understand the labs more. What does that mean to you?”—to “fill in” (Hutchinson, 1988) this emerging core category.

When students were asked about what they liked and disliked about their laboratory experiences, their responses closely matched the survey responses. Evidence
of all three categories was apparent. Learning goal comments mirrored the idea that labs help explain the lesson: “Labs pulled it together” (Interview 11), and “It’s good to see that stuff really does happen” (Interview 9). Affect issues remained the same as those found in the survey: “Cool labs hooked us back” (Interview 3), and “It makes science classes different than other classes” (Interview 7). And format issues and suggestions were much the same: “not enough time” and “I couldn’t get the point” (Interview 7).

I expected to find the likes and dislikes mentioned in the interviews the same as the survey responses; however, the elaboration on the core category of this study was the primary purpose of the interviews. Note this interaction between the researcher (R) and Interviewee 9 (9), a junior girl, who stated she sometimes liked labs, when asked the question “What makes the difference between a lab you like and one you dislike?”

9: Understanding it.

R: Understanding what?

9: The concept. I hate the questions at the end like, like they’re really pointless, and you don’t understand, and you have to think really hard, and the teacher won’t answer your questions, so you struggle to figure out the whole thing, and it gets really stressful because it’s due like at the end of class.

R: By understand do you mean understand what the words are saying so that you know what to do next, like to do the procedure, or understand the concept the lab is trying to do?

9: The concept.

R: The concept of what the lab is trying to do.
9: I think with some of the labs, they kind of did stuff and then at the end, like, they asked us questions, and I didn’t even know that they were tying that in with the lab . . . it didn’t seem like they were related.

R: What would fix it?

9: Like, reading the lab?

R: No, no, not what would you do different, what would I do different. What would teachers do?

9: I don’t know, like explain what we’re going to do, like, with some of the labs we’ll be doing something, and it just seems pointless, and at the very end we’ll be like “Oh, OK.”

This passage contains not only numerous comments mentioned by others about labs but also how they cross over and distill into whether or not the student understands the lab. Some may interject at this point that having students struggle to figure things out is a good thing; however, Interview 2 added an interesting comment to this discussion: “There is a difference between figuring it out on your own and not even understanding it.”

Some interviews focused (by interviewee choice) primarily on the link between the value of a laboratory experience and whether or not the student understood the reasoning behind the lab. After noting that the value of the experience depends more on the teacher and how he or she uses the lab more than the lab itself, in Interview 1 a senior male said, “Labs are only useful if the instructor uses them right.” Other students added, “Once I knew what I was doing, then they helped” (Interview 5), and “if you don’t know
what you are doing, it’s not enjoyable at all” (Interview 6). The data “filled in” around this idea of student understanding. The interview data shows students needing to understand the point of the experience, understand it nearly immediately (Interview 12), and if not, the experience turned into one that students “just [want to] get . . . done” (Interview 7).

Interestingly, many of the interviewees (8 of the initial 12) had positive comments about a type of laboratory experience in which the student was to see what is already known, better known as the “verification” lab. Although this type of lab has been used in classrooms since the 1800s (DeBoer, 1991), it has not been highly regarded in the literature (Herron & Nurrenbern, 1999; McComas, 2005; Montes & Rockley, 2002; National Research Council, 2002; Tobin et al., 1994). A type of lab generally well regarded in the literature is the “guided inquiry lab” (Igelsrud & Leonard, 1988); however, many students reacted negatively to this type of lab, some even referring to it by name. When questioned further, many of these students had been recently exposed to this type of laboratory experience by several student teachers. Of course, it is possible that their attitudes derived from the inexperience of the student teachers or their delivery of the experience. Many other factors could have caused this unexpected reaction; however, the student perspective in this study shows that students favored verification labs over guided inquiry labs. More elaboration on this point has been included in the discussion in the following chapter.

Although teachers typically see a difference between understanding in the sense of understanding the directions and understanding the concept or the learning goal, the
students did not draw this distinction. They viewed the experience more as a whole. If they lost understanding anywhere in the process, for them learning ceased; and “just getting it done” (Interview 3) was their goal. This point broadens the core concept to include all facets of student understanding. Students believed they needed to understand (a) why they were engaging in the experience; (b) how to complete the laboratory experience; and (c) what the experience was designed to show them. A breakdown in any of these aspects disrupted the learning process and eliminated any value of the laboratory experience.

At this point in the study, the core category came into a sharper focus, one that could be called the theory generated by this data. Specifically, this grounded theory states that the student perspective on laboratory experiences, although varied, can be divided into three main categories: (a) learning goal issues (comments about the laboratory experience helping or hindering the classroom goal of the teacher), (b) format issues (positive and negative comments about the physical setup or instructions), and (c) affect issues (comments based on likes and dislikes from an emotional angle). Although these categories are helpful, the overarching point and true generated theory can be stated thus: If students lose their understanding at any point in the experience, the activity loses all educational value for them. They have an innate desire to understand the reasoning behind the experience, to understand the way to accomplish the experience, and to understand what the experience was intended to help them learn. This point of student understanding appeared at the outset of data collection: “a lot of ‘if I understand it, I like it; if it confuses me, I don’t’” (Lambert, Researcher memo, July 10, 2007); and “[students
are making a big deal about clarity; either understanding directions or getting the point or understanding outcome” (Lambert, Researcher memo, July 12, 2007). And it appeared often—in 70% of the researcher memos. Not only had the core category emerged, but the theory grounded in the data evolved as well.

At this point the data showed saturation, which Strauss and Corbin (1998) defined as “the point in category development at which no new properties, dimensions, or relationships emerge during analysis” (p. 143), to which Charmaz (2006) added, “when gathering fresh data no longer sparks new theoretical insights nor reveals new properties of your core theoretical categories” (p. 113). Basically saturation occurs when data collection ceases in grounded theory, the point at which rigor and quality become important. Many of the requirements for quality work and saturation, such as protracted time in the field, looking for contradictory data and theories (Hutchinson, 1988), and a continuous revelation of the core category, may have occurred; however, claiming saturation is dangerous if done uncritically (see Charmaz, 2006, p. 114). One more data collection technique was used to verify that the data was saturated and to establish reliability and validity.

Teacher Focus Group on Student Understanding

To explore further the core category of “student understanding,” a teacher focus group was formed to respond to the data gathered to this point and give fresh insight into its possible meanings. The focus group consisted of nine teachers; eight science teachers from the school studied and one teacher from a different department selected to represent a non-science teacher perspective. The focus group also served as a means of
triangulation of data sources. Denzin and Lincoln (1994) stated, “[The] use of multiple methods, or triangulation, reflects an attempt to secure an in-depth understanding of the phenomenon in question. . . . Triangulation is not a tool or strategy of validation, but an alternative to validation” (p. 2).

I summarized the common student responses, categorizing them into affect issues, learning goal issues, and format issues, and the evolving core category. The focus group then addressed the following two questions: “Students consistently say they want to understand the labs better. What does this mean to you?” and “Do we (as teachers) spend as much time on our labs, integrating them into the flow of class and making sure the students get the point, as we do our lectures, demos, and other activities?”

Teacher responses to the first question indicated a high level of agreement with the students’ expressed need to understand what they are doing and why. Some comments include the following: “I agree that if students do not understand the directions or the purpose of the lab that they will be frustrated and not enjoy the lab experience”; “I think the survey results reflect accurately how students feel about the lab work I require”; “Fantastic! I would like them to understand the labs more, too! In this regard, they are right. That is what it’s all about”; and “In most students there is a ‘natural’ desire to understand what they are doing in a lab and why things are so.” Thus, the group affirmed the core category and verified the hypothesis that saturation of the data had been reached.

After agreeing with the student perspective, the teachers in the focus group quickly provided their opinions on reasons for the lack of student understanding of some laboratory experiences, for example, “Students do not listen when given verbal
instructions or do not read the instructions that are provided for them.” When asked about the obstacles to student understanding, the teachers responded: “Students do not pay attention to or read directions”; “Students will bypass directions and go directly to the gathering stage”; “Obstacle number one is failing to read the directions”; and “Find a way to ensure they read the directions.” Many of the comments focused on student effort: “One obstacle to helping students understand labs is their lack of effort to do so”; “Kids don’t want to be bothered with the ‘why’ and ‘how does this relate’ questions”; and “If, as the survey suggests, they are concerned about understanding a lab, then they should be making the effort to do so. It appears that their level of concern is not such to motivate them to seek the information necessary to understand what they are doing and why.”

With further probing, the discussion returned to reflection on what part teachers may have in the process and the delivery of lab activities. As the discussion continued, many of the comments turned to problems exemplified by the teacher who said, “I don’t really get a chance to integrate the labs into the regular class,” and then to what many considered the underlying problem, namely a lack of time—“I need more time.”

Only with deeper reflection can any science teacher see beyond what is obvious every day (lack of effort or failure to follow directions) and determine what must be done to improve the teaching and learning processes. For example, direct instruction may be necessary. Although this is not a favorite of students by any measure, teachers know that direct instruction is sometimes necessary. They must move beyond the temptation to say students are bored and don’t listen and instead determine what must be done to improve the experience.
In summary, the discussion among the teachers in the focus group followed a path many readers may follow. First, they acknowledged the student perspective, reacted to what appeared to be but was in actuality not an indictment of teachers, and concluded by reflecting on what could be done to improve student understanding. The primary purpose of the focus group was accomplished as teachers verified the validity of the core category, found it logical, and ended by reflecting on their part in possible solutions.

Final Data Issues: Reliability and Validity

With the unique perspective of the teacher focus group paired with student data showing saturation, the final step was to compare the generated theory against the rigors of good science. Terms such as reliability and validity usually define this discussion; however, grounded theory methodology requires some modification of the vocabulary even though the ideals remain. Similarly, Strauss and Corbin (1990) related:

Grounded theorists share their conviction that the usual canons of “good science” should be retained, but require redefinition in order to fit the realities of qualitative research, and the complexities of social phenomena that we seek to understand. (pp. 249–250)

Most writers on grounded theory have cited the thoroughness of the methodology itself, or the “rigor of systematic generation of theory” (Glaser, 1992, p. 30), as the main producer of quality work. Strauss and Corbin (1994) asserted that verification and validation are found “throughout the course of a research project” (p. 274). In other words, the diligence required in choosing appropriate data collection techniques, the continuous comparison between theory and data collected, and transparency during the
concurrent data analysis to “show its workings” (Holliday, 2002, p. 8) were sufficient to ensure solid grounded theory. Morse and Richards (2002) held a similar position: “Through detailed exploration, with theoretical sensitivity, the researcher can construct theory grounded in data” (p. 54); and Creswell (2002) added that “validation is an active part of the research process” (p. 458).

The methodology was followed; therefore, the work is good. Such a stance is tempting, but other writers have provided additional, more concrete suggestions by which to judge grounded theory. Charmaz (2006) suggested four criteria for evaluating grounded theory: credibility, originality, resonance, and usefulness” (pp. 182–183).

Credibility

A study with credibility is one in which data have clearly represented the research context: The data reveal “intimate familiarity with the setting”; the categories cover a “wide range of empirical observations”; and “strong logical links between the gathered data and your arguments and analysis” are apparent (p. 182). LeCompte and Goetz (1982) added the need for a “match between scientific categories and participant reality” (p. 43). The point is not reliability in the replicable sense but to “give actors voice even in the context of our inevitable interpretations” (Strauss & Corbin, 1994, p. 281). Hutchison (1988) asserted, “The question of replicability is not especially relevant [because] the point of theory generation is to offer a new perspective on a given situation that can then be tested by other research methods” (p. 132). This study reached all these benchmarks. The three original categories of affective, format, and learning goals covered nearly all the comments given in the open-ended surveys. No major comment or
opposing theory was discarded in the coding of the data. Only obviously frivolous comments, such as “more blowing things up” and “I don’t like goggle marks” were omitted from the data analysis.

Two outside readers who verified the credibility of the chosen categories were high school science teachers with understanding of laboratory experiences. These teachers were teachers at the school studied but were unfamiliar with the study particulars. The first outside reader was given the raw data (student comments from the open-ended survey) and an explanation of the categories derived as well as the eventually evolving core category. The reader was asked to look at the data and verify that the chosen categories made sense; in addition the reader checked to determine whether the emerging core category met the demands of credibility. The second reader was given the data without categories or any analysis and asked to categorize them in his own way into a small number of categories. The readers’ responses confirmed the categories and the emerging theory. The first reader’s remarks were simple: The categories chosen “make sense,” and the core category “seems obvious. It’s something we deal with in every lab” (B. Marquette, personal communication, July 21, 2008). The second reader’s comments were more elaborate; he divided the data into three categories: “experiential, cognitive, and application” (C. Carmen, personal communication, June 30, 2008). Concluding that these categories closely aligned to the chosen categories of this work was simplified because the reader included his axial coding of the data. The most obvious link was in the reader’s cognitive category resembling the learning goal category of this study. Comments coded in this work as affect were usually categorized as experiential because
the outside reader focused on the experience for the student. Finally, the data categorized as format issues here were usually categorized as application issues, indicating the struggle teachers face in terms of “how to do it.” Of course, the categories were not perfectly matched; but once given the categories chosen here, this outside reader noted, “It seems like they’re pretty similar” (C. Carmen, personal communication, June 30, 2008).

One of the most telling credibility marks derived from focus group reactions to my findings. All teachers agreed that they have often heard student comments on understanding. Many had thought about helping the students in this area yet were handicapped by a number of issues, such as time, materials, and knowledge of other options. The final grade on credibility comes from the reader of this study, who must ask whether or not the categories and generated theory seem credible.

**Originality**

To determine originality, the researcher much ask, “Does [the] analysis provide a new conceptual rendering of the data?” (Charmaz, 2006, p. 182). The categories elaborated do not constitute new ideas and neither does the idea that students’ understanding of the laboratory experience is important; but the true generated theory—that the student view of these experiences is highly distorted by whether or not they understand the experience (from beginning to end)—provides the fresh look introduced in chapter 1. Furthermore, the data challenges some of the current literature on verification laboratories. I do not suggest that all labs should be of the verification type but that these labs have a place and may be more valuable than currently held.
Resonance

Creswell (2002) implied that resonance illuminates the “macro-picture of educational situations rather than a detailed micro-analysis” (p. 456). Charmaz (2006) defined it in terms of its conveyance of the “fullness of the studied experience” (p. 182). As with credibility, the generated theory must “make sense to . . . participants.” In this study a resonance checkpoint occurred in the transition from the survey data to the interview data. As each interviewee was asked about the emphasis on understanding laboratory experiences, an opportunity arose for the theory to show resonance or not. Each participant readily accepted the theory and in each case contributed to making it a fuller more robust theory. In addition the theory made sense, or resonated, for each of the members of the teacher focus group.

Usefulness

The last criterion Charmaz mentioned is usefulness, which requires little definition and was the driving force behind this study. Because only by the readers of this study can determine usefulness, argument is impossible. According to Charmaz, when grounded theory is evaluated, the primary concern is the audience—in this case teachers or colleagues—who will judge the usefulness of the methods in terms of the quality of the final product (p. 182). As a teacher addressing other teachers, I acknowledge that usefulness is a major consideration. The implications of this study will be elaborated in the next chapter, but simple knowledge of the student perspective on laboratory experience is useful in itself. From this simple knowledge, individual teachers may reflect on their own perception of student understanding of laboratory experiences, both in
general and as individual activities. This reflection may cause a reevaluation of some activities and modification of others. Time allotted may need to be changed, and the time spent before and after the laboratory experience in explanation or discussion may also change. In some ways, giving the student a voice concerning her or his opinion of this important curricular piece may be the most important element of this study. Implications and opinions presented here are confined to the context and reflection of the researcher. Reflection on this knowledge by professional teachers will exert the greatest impact on students in the long run.

The foregoing discussion shows that data saturation was accomplished. In the next chapter I have elaborated on some pragmatic issues associated with the core category and its generated theory.
CHAPTER 5

DISCUSSION

Introduction

Chapters 1 through 4 traced data gathering and analysis, division of the data into three categories, and the emergence of a theory grounded in this data, simply stated as follows: Students desire to understand the *why do*, the *how to*, and the *what it means* of laboratory experiences. Lacking any one of these, the experience loses educational value for them. This chapter covers the practical implications of the data and the theory for science educators as they work to educate young people effectively.

Implications

The implications of this work primarily concern science educators as they make decisions on the everyday work students perform and observe. The unfortunate reality is that science teachers are already beleaguered by lack of time, materials, and other curricular supplies as they try to design what is best for their students. Some science teachers reading this study may think, “I already help them understand” or “This is just another consideration I don’t have time for.” My intent is that this data will help them reflect and “work smarter, not harder” for the benefit of the student. To accomplish this goal, the discussion will be divided into two parts: (a) how the student perspective on understanding affects the teacher’s view of time spent in the lab, and (b) how the student perspective on understanding affects how teachers think students should learn from laboratory experiences.

*Possible Changes in How Teachers View Time Spent in the Laboratory*

102
A student who noted liking labs sometimes suggested the following on the open-ended section of the survey:

I think sometimes labs are pointless, and the teachers know it but do them anyway. . . . Labs should be something kids can relate to but work hard at the same time. To make labs better, I think they should be fun; and the point of the lab should be more apparent.

The second part of this quotation links directly with the core category; however, the first part of the statement is noteworthy. Do science educators sometimes engage students in activities they know are pointless? The answer is most often “no,” but perhaps the students simply do not grasp the point of the exercise. If this is the case, then the more complex answer entails helping them understand the point. Do science teachers choose labs for reasons other than curricular reasons? The following researcher reflection emerged near the completion of this project:

I think every teacher would say they do labs to help students understand and that one of their main goals is that students understand. But do we really? Are we caught sometimes doing labs for other reasons, doing labs we know they will have a hard time understanding, doing labs we think are cool, or classic, or . . . .

(Lambert, Researcher memo, January 24, 2008)

Perhaps it is a laboratory experience the teacher enjoys or is easy or gives the students a break or even gives the teacher a break. Some of these reasons may be legitimate, but teachers must remain aware that students think “the instructor couldn’t come up with anything else to do, so here’s a lab” (Interview 1). Recall that primary criticism cited by
students across all groups was that some labs are boring or pointless or constitute busywork (214 mentions in the open-ended survey data).

The researcher was a full-time science teacher at the time this study was conducted, and researcher memos on this subject reflected as follows: “It would be difficult to maintain a classroom in the middle of a lab where we stop and make connections during the lab time. We’ve created a culture where the lab is time off from learning/teaching” (Lambert, Researcher memo, January 3, 2008). This is, however, far from an indictment on science teachers. By their very nature lab times are viewed as times for fun and have been from the outset of students’ educational process. The data often revealed positive feedback on lab experiences because they involved no lecture; labs were often described as fun or cool. Science teachers, who may be partially responsible for students’ difficulty in reconciling that an activity can be both fun and educational, may believe that if they engage students in a quality activity, students will make that connection as easily as the teachers do (Driver, 1983).

With regard to the core category of student understanding, if students understand that some point to learn underlies every activity in which they engage, then this culture of “time off” may be disrupted. Two researcher memos conveyed this point:

Almost as many students want to understand what it [the lab activity] was about as those who just want it more fun. Interesting that taking the time to make it relate, explain it, would take away time from other things that might improve cognitive gains. With so many students viewing labs as having no point, it might be more of the explanation thing. They need to see our point. It may be inch deep
thing. Fewer labs, but more explanation on labs we do. We’ve taken up the challenge to make our day-to-day teaching more relevant/fun/engaging. Students seem to be asking for us to do the same to our labs! Many of our labs are done exactly the same way they were decades/centuries ago. (July 12, 2007)

The second memo follows:

We spend a great deal of time on our craft (teaching) when we are “performing” or are the focus of the day. Yet do we spend as much time, thought, and effort in

- Evaluating
- Integrating
- Explaining
- Reflecting on
- Determining the efficacy of our labs?

We spend time, but on

- Setup
- Safety
- Timing
- Format (to make sure it works)

I wonder if we are worried that if we looked deeply at the efficacy of some of our labs, we might lose them and lose something we like, lose time off we need, lose something we think is cool. (September 9, 2007)
Teachers have many tools at their disposal to help illustrate the concepts they are teaching: Video clips, animations, web pages, demonstrations, and other techniques have found their way into modern science teaching. They work hard at (a) putting each of these in the correct place in the curriculum, (b) keeping students engaged during its use, and (c) making sure the students understand the point after the conclusion of the activity. Do teachers treat laboratory activities similarly, or do they look at the lab activity itself as the primary teacher and somehow responsible for the learning.

Many science teachers may already integrate, engage, and explain as the students recommended. This study is bound by its context and by the researcher as a part of the study, not a removed objective observer. Thus, conclusions reflect the researcher’s own views on his laboratory activities and may not be representative of those of others, yet the data gathered in this study suggest a disconnect between the value science teachers see in some activities and the value the students find in them. When it occurs, simple teacher reflection on the laboratory activity and its value may cause some activities to be discarded, some to remain the same, and some to be more deeply integrated into classroom learning:

The obvious reason we may not be seeing cognitive gains from labs is not the concept of the lab itself but how we have traditionally used them and how we often fail to integrate them enough for the student for them to make connections.

(Lambert, Researcher memo October 11, 2007)

Possible Changes in the Way Students Learn in the Laboratory
An earlier trend in science education promoted the discovery lab, in which students are given the materials and expected to discover the concept. This idea has been discredited in the literature (Driver, 1983) as well as in the classroom, where it failed and was replaced by the lab activity featuring guided inquiry, in which students are given an idea of what they are looking for or how the materials are to be used. On the Process Oriented Guided Inquiry Learning (POGIL) website, these activities have been defined as follows: “Materials supply students with data or information followed by leading questions designed to guide them toward formulation of their own valid conclusions—essentially a recapitulation of the scientific method.” These differ in format from the more directive laboratory activities like verification labs, which have been criticized in recent literature along with other so-called level 1 labs (McComas, 2005) (Herron & Nurrenbern, 1999; McComas; Montes & Rockley, 2002; National Research Council, 2002; Tobin et al., 1994).

In this study, however, the open-ended surveys and the student interviews yielded more positive feedback on verification labs and more negative feedback on the open-ended formats, especially guided inquiry. The difference between the student perspective in this study and accepted current research in laboratory activities requires investigation. Why does a student who did not like labs write, “I especially don’t like the labs that we do before we learn about the topic. I find it difficult to apply them.” Why did a senior reflecting on a full 4 years’ worth of high school laboratory experiences say, “I think they are better at reinforcing because if they serve as the critical piece, they are often too vague or not to the point” (Interview 6).
Perhaps the use of inquiry-type lab experiences reflects teachers’ views of laboratory exercises as a representation of “real science.” A teacher in the focus group voiced this position very well:

I choose to assign lab work primarily to provide students the opportunity to experience the scientific method through scientific inquiry/investigation/experimentation. Typically my labs guide students through the whole process from questioning to conclusion. By the time they leave my class, I intend for them to not only understand the scientific method, but to be scientists!

Much has been written on real science in the classroom, but the focus here is how teachers view laboratory time and how that may explain some of the divergent student perspectives. Two researcher memos shed further light on this discussion:

Perhaps we feel a need as teachers to protect the image of what real science experimentation looks like (we have our teacher idea of what science looks like). Few directions, all inquiry, may work or not, no interruptions to direct [give instructions], etc. This is all good at times. But what kids sometimes need is that connection between the conceptual world and the real world. (Lambert, Researcher memo January 3, 2008)

We think of exploring and hope that understanding tags along. Perhaps we should focus on understanding and do it within the theme of exploring (or as close as we can come with understanding happening). (Lambert, Researcher memo January 4, 2008)
The real question centers on where high school laboratory activities fall on the science continuum with child’s play on one end and full-blown research laboratory work on the other. Of course, elements of play extend all the way up through the continuum as methods of exploration extend down, yet we certainly must do more than simply invite students to play with “cool stuff.” By the same token, neither are students ready for the rigor of the research laboratory. The argument here is not to eliminate inquiry or open-ended exploration; it is instead to question whether teachers have pushed laboratory activities too far to the end of the continuum where students are asked to imitate the “scientist in the laboratory” to the degree that their understanding is impaired.

The data from this study suggest repeatedly that students are frustrated about their lack of understanding the laboratory experience. Consider the following excerpt from the researcher memos:

Our students still have a need to “do it right.” We need to meet them where they are rather than expect them to meet our idealized view of what science exploration looks like. . . . We completely deny the fact that some students may need directions they understand with an outcome that is assured (and safe) and the confidence that comes from getting what you were supposed to. Without this for some students, they never will get to the exploratory stage; they remain in fear, confusion, and get the attitude they just can’t do labs or just don’t like labs.

(Lambert, Researcher memo, January 3–4, 2008)

This data can’t be dismissed as peripheral or typical only of students who dislike labs or lack maturity. The desire to understand labs surfaced in all groups and emerged as the
core category when considering the student perspective. Students apparently perceive inquiry and understanding as opposing forces, necessitating encouragement from science teachers to break down this thinking and show how one may actually inform the other. As far as laboratory activities are concerned, teachers must gauge the level of inquiry inherent in the activity to assure both student understanding and to promote (at least not squelch) students’ further development in inquiry until they can reach the maturity to engage in full exploration on their own.

References to the current literature that began this section indicate that the guided inquiry lab and its predecessor, the discovery lab, lie at one end of the spectrum of activities in which high school students are treated as ready for full open-ended inquiry. What teachers intend to accomplish with the laboratory activity must be considered:

The discovery (i.e., guided inquiry) we are looking for is not the concept (like density or Boyle’s law), but instead the discovery we are trying to help them make is the connection back to past learning and the scaffolding to new knowledge. This is what constructivism is all about and how it relates to labs. Don’t help or expect them to make (actually remake) the discovery but rather discover the connection, their perception, and how they would correctly use the idea at hand. It’s actually discovering integration (with growth), not conceptual discovery. (Lambert, Researcher memo, October 11, 2007)

Driver (1995) stated that this experience by itself is not enough. It is the sense that students make of it that matters. If students’ understandings are to be changed toward those of accepted
science, then intervention and negotiation with an authority, usually the teacher, is essential. (p. 399)

One should not conclude, however, that high school science class is no place for an inquiry lab. The implication is that teachers must evaluate the laboratory activities they do and chose carefully the level of inquiry for each activity. “There is a place for these labs; in fact, a verification lab with an expected outcome may be exactly what some students need some of the time. Instead of dismissing a type of lab, we should realize they are all tools in our bag and at times we will need that one” (Lambert, Researcher memo January 2, 2008). Likewise sometimes an inquiry type lab is the best choice.

For example, consider two common high school chemistry laboratory activities. In one laboratory activity students investigate Boyle’s Law, which states that for a fixed amount of gas, as the volume decreases, the pressure increases and visa versa. Here an inquiry lab can work quite well; the student can be given a fixed sample of gas in a container with a variable volume and something to measure the gas pressure. With a little exploration students can discover the relationship, upon which they can later build to find the equation that symbolizes Boyle’s law. In another lab students are given a sample of a hydrated ionic substance. They heat the substance, and the water is driven out of the crystals, making the sample lighter. If the point of the activity is to show the sample getting lighter or changing color, then inquiry may work; however this activity is often associated with finding the formula of the hydrate. Doing so involves a great deal of math and some concepts that are relatively new to the student. No amount of guided inquiry will work here (unless the definition of guided inquiry is expanded to include about
everything). This is the type of lab that when forced into an inquiry mold can leave students confused and frustrated; it exemplifies a well-intentioned attempt at inquiry, leading to the data observed in this study.

The implication boils down to science teachers reflecting on their class and the activity and choosing “the right tool for the job.” Contemporary researchers have a great deal to say about making labs more inquiry based. A better compromise may involve moving toward more inquiry yet remembering that sometimes inquiry is not the best avenue. One example is embodied in Wilson and Stensvold’s (1993) reclassification of laboratory activities into three inquiry-rich categories: generalization, resolution, and confirmation; another, in Peters’ (2005) work on reformatting laboratory activities: “Reforming cookbook labs into critical-thinking labs could be the intermediate step that helps teachers reach the goal of providing inquiry based opportunities for their students” (p. 16). McComas (2005) classified laboratory activities into three levels, each progressively more inquiry based. Although I have argued against teachers’ exclusive use of level 3 activities, the move toward higher inquiry labs is certainly justified, a position that matches many of the implications mentioned here: “Considering the level of the laboratory can help teachers make informed choices about the impact that a particular activity might have on student learning and motivation, and help move activities toward higher levels of inquiry” (McComas, 2005, p. 25). Wallace and Kang (2004) stated that students can learn concepts as well as the nature of science by engaging in rich problem-solving activities, and they do not necessarily have to derive theory from their hands-on investigations. These two authors suggested “that a view of inquiry as application and
problem solving after concept introduction may be more viable in the secondary classroom than inquiry as induction of concepts’’ (p. 958).

Science teachers today are affected daily by a large number of stressors: Lack of time, lack of materials, inadequate classrooms, standardized tests, outdated and inadequate curricular materials are only a few of them. Laboratory activities should not be imposed on them simply because they are inquiry based or someone’s pet lab or because they appear in the lab book purchased with the classroom text. Teachers need to be given the time to (and have the inclination to) evaluate activities and determine how best to integrate them into the class’s curriculum.

Summary

This study began with a view of the public school science laboratory in America as seen by the editors of *Time* magazine and the authors of *America’s Lab Report: Investigations in High School Science*. The present study was based on high school students’ perceptions of the laboratory experience. As the study progressed, the core category from the student perspective distilled into the students’ desire to understand all facets of the laboratory experiences to which they were exposed: the why do it, the how to do it, and finally, what the results mean. Some of these ideas are buried in *America’s Lab Report*: “Students [may] do a laboratory activity, [but] they may not necessarily understand what they have done” (p. 82); and the “unique features [of labs] make it a challenge to structure laboratory experiences so that they neither overwhelm students with complexity on one hand nor rigidly specify all of the questions, procedures, and
materials on the other” (p. 117). These are a few of the ideas illuminated by the student perspective.

The implications derived from this student perspective focused on what science educators need to do to improve the overall state of laboratory experiences. As is often the case, the primary factor is time—time to reflect on and evaluate the current laboratory work to which students are exposed and time to improve those experiences that are not meeting students needs. An interesting question develops: Science teachers are trained to teach, to incorporate cooperative learning and myriad other techniques into their classrooms; but are they trained how to integrate labs for student understanding? Some teachers have asked for this type of training:

I have not learned how to facilitate real thinking and essential planning for authentic lab experiences. I don’t know what students really need in an introductory chemistry experience at the high school level, and I cannot figure out how to teach logical thinking and sequencing to 20+ students in lab at the same time. My time management skills are lacking. There’s much more, too. . . . I was not trained or shown how to conduct labs. I had to learn it on my own. . . . Many teachers in my district, which is well-funded and well equipped, lack the confidence to conduct lab experiences. . . . Most of the problems center around getting the individual teacher to accept that labs are integral to the understanding of science. (Improving the Laboratory Experience for America’s High School Students, 2007, pp. 26–27)

Many researchers have also noted that such training is not available.
Unfortunately, teachers generally lack formal training in the methods, rationale, and research base relating to the laboratory as a special instructional arena, and commercially prepared laboratory exercises present cookbook activities demanding low-level cognitive abilities on the part of students. Therein lies the problem. (McComas & Colbum, 1995, p. 120)

Furthermore, “professional development should be developed and offered that helps teachers emphasize both science content and process when engaging students in science laboratory experiences” (Campbell, 2007, p. 52). One possible solution then is to design professional development to help teachers foster enough discussion for understanding without inhibiting inquiry.

At the inception of this study many variables and possible avenues of inquiry were introduced. This study focused on student understanding but there remain many avenues yet to be fully explored, some of which may be informed by the data already collected. These lines of inquiry include:

- Does the affective domain, while obviously prevalent in the data, influence cognitive results?
- Does student dislike for group activities affect their opinion of laboratory activities?
- What is the student definition of a laboratory activity?
- What makes a laboratory activity boring or viewed as busy work from the student perspective?
• What is the student perception of other activities that are not in the often normal lecture/recitation vein?

The implications of this study also suggest further questions for research. This study lays only the groundwork for additional study. Possible future questions include the following:

• From the student perspective does a difference exist between not understanding the procedure and later not understanding the results?

• As students mature, what are the factors that determine student preference for inquiry as opposed to activities with less inquiry?

• If more time were spent fostering student understanding of lab experiences, would classroom cognitive gains increase?

• If more time were allotted for laboratory experiences, how would teacher use that time?

• Would the conclusions be the same with a different group of students?

This work is not the end of the discussion on laboratory experiences, not even on the student perspective on these experiences. It is not a grand work on human behavior (Creswell, 2002) or a “minor working hypothesis” (Glaser & Strauss, 1967, p. 33) but a middle-range theory (Charmaz, 2000). Charmaz (2006) would be skeptical if a study such as this contradicted current research. This study does not do so and merely augments the discussion on what is the best for America’s science students. Unexpected results emerged; for example, student interest in the lab topics was mentioned often but was not nearly so common across all groups as the final generated category of understanding. In
this study I attempted to give the student some voice in the discussion of laboratory experiences. With clear voices students said they want to understand the experience. The final words belong to the students as they suggest improvements to laboratory experiences:

- “Showing us how they’ll help us to understand what we’re working on and getting rid of the small pointless ones that don’t make sense.”
- “If the point that the teacher is trying to get across is easier to understand or more clearly demonstrated in the lab.”
- “Not having them at all. Maybe actually being able to understand them.”

Their words give all interested parties something to think about.
APPENDICES
Appendix A
Appendix A

Student Survey

What do you think about science labs?
(Project Title: Exploring the Student Perspective on High School Laboratory Experiences)

Hello Young Science Student,

My name is Mr. Lambert. Some of you know me, some of you have heard about me, and to some I’m just one of those weird science teachers. I’m doing research for my dissertation at Kent State University about what you, the science student, thinks about science labs. Most of you have an idea what a science lab is, but just in case, we’re going to call it anytime you interact with materials or models to help you understand science. Of course, this survey is voluntary. Your answers will remain anonymous; no one will know who you are or what you said. If you want to quit at anytime, go ahead. And if you don’t want to participate at all, that’s just fine, too. But if you can, please give me your honest opinion. As you work to learn science, we science teachers also struggle about how best to teach science. No one may ever have asked your opinion about labs before. Yep, you now have the chance to be part of original research. I hope you can give me some insight. If you have any questions or comments, please feel free to call me at (330) 325-2564.

Also, if you would like more information about KSU’s rules for research, it can be obtained from Dr. Peter C. Tandy, Acting Vice President and Dean, Division of Research and Graduate Studies (330) 672-2851.

QUESTIONS 1-10 PLEASE CIRCLE THE BEST ANSWER:

1) What year are you in school?

2) How many science courses have you taken at the high school (grades 9–12) including this year?
   a. 1  b. 2  c. 3  d. 4  e. 5 or more

3) Do you think you might eventually have a career in science?
   a. Yes  b. No  c. I don’t know

4) How are you doing in your current science class?
   a. Above average  b. About average  c. Below average

5) What part of science classes do you most like?
   a. Wonderful lectures  b. Fascinating demonstrations  c. Those magnificent labs
   d. Fun group work  e. Other (please tell me about it) _________________________

6) What part of science classes do you least like?
   a. Wonderful lectures  b. Fascinating demonstrations  c. Those magnificent labs
   d. Fun group work  e. Other (please tell me about it) _________________________

7) Why do you think we (teachers) make you do labs?
   a. To help you discover an idea we’re about to talk about
   b. To have you see for yourself that what we’ve just told you is correct
   c. To help you get an idea of what being a real scientist is like
   d. To keep you interested in science. It’s fun.
   e. To keep you occupied
   f. Other (please tell me about it) _________________________

8) What do you think is your teacher’s opinion of labs?
   a. Loves them  b. Doesn’t like them  c. Is afraid of them  d. It’s just something we do

9) About how many labs do you do in a week?
   a. 1 or less per week  b. 1–2 labs per week  c. more than 2 per week

10) Do you think you will take a science class in the future (in high school, college, etc)?
    a. Yes  b. Probably, but I don’t want to  c. No
Please turn over and finish Question 11

11) In general, do you like labs?  
   A) YES  
   Please go to Section 1  
   B) NO  
   Please go to Section 2  
   C) SOMETIMES  
   Please go to Section 3

If you answered “yes,” why do you like labs? (List all the reasons you can think of.)

Briefly describe a lab you liked and why you liked it.

Is there anything about labs you don’t like?

If you answered “no,” why don’t you like labs? (List all the reasons you can think of.)

If you can, give me an example of a lab you disliked and why you disliked it.

Is there anything about labs you like?

If you answered “sometimes,” could you explain that to me a little more? Why do you like some labs and not others?

Give me an example of a lab you liked and an example of one you didn’t and briefly explain why.

Everyone please answer: What could make labs better?
Appendix B
### Appendix B

Results of the Multiple-Choice Section of the Survey

**Question 1: What year are you in school?**

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 9</td>
<td>233</td>
<td>35.0</td>
</tr>
<tr>
<td>Grade 10</td>
<td>224</td>
<td>33.7</td>
</tr>
<tr>
<td>Grade 11</td>
<td>167</td>
<td>25.1</td>
</tr>
<tr>
<td>Grade 12</td>
<td>41</td>
<td>6.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>665</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

**Question 2: How many science courses have you taken at the high school (grades 9–12) including this year?**

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>228</td>
<td>34.3</td>
</tr>
<tr>
<td>2</td>
<td>217</td>
<td>32.6</td>
</tr>
<tr>
<td>3</td>
<td>142</td>
<td>21.4</td>
</tr>
<tr>
<td>4</td>
<td>47</td>
<td>7.1</td>
</tr>
<tr>
<td>5 or more</td>
<td>28</td>
<td>4.2</td>
</tr>
</tbody>
</table>
Question 3: Do you think you might eventually have a career in science?

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>157</td>
<td>23.6</td>
</tr>
<tr>
<td>No</td>
<td>302</td>
<td>45.4</td>
</tr>
<tr>
<td>Don't Know</td>
<td>199</td>
<td>29.9</td>
</tr>
</tbody>
</table>

Question 4: How are you doing in your current science class?

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above Average</td>
<td>251</td>
<td>37.7</td>
</tr>
<tr>
<td>About Average</td>
<td>324</td>
<td>48.7</td>
</tr>
<tr>
<td>Below average</td>
<td>88</td>
<td>13.2</td>
</tr>
</tbody>
</table>

Question 5: What part of science classes do you most like?

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wonderful lectures</td>
<td>33</td>
<td>5.0</td>
</tr>
<tr>
<td>Fascinating demonstrations</td>
<td>189</td>
<td>28.4</td>
</tr>
<tr>
<td>Those magnificent labs</td>
<td>149</td>
<td>22.4</td>
</tr>
<tr>
<td>Fun group work</td>
<td>146</td>
<td>22.0</td>
</tr>
<tr>
<td>Other</td>
<td>65</td>
<td>9.8</td>
</tr>
</tbody>
</table>
**Question 6: What part of science classes do you least like?**

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wonderful lectures</td>
<td>413</td>
<td>62.1</td>
</tr>
<tr>
<td>Fascinating demonstrations</td>
<td>14</td>
<td>2.1</td>
</tr>
<tr>
<td>Those magnificent labs</td>
<td>64</td>
<td>9.6</td>
</tr>
<tr>
<td>Fun group work</td>
<td>54</td>
<td>8.1</td>
</tr>
<tr>
<td>Other</td>
<td>95</td>
<td>14.3</td>
</tr>
</tbody>
</table>

**Question 7: Why do you think we (teachers) make you do labs?**

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>To help you discover an idea we’re about to talk about <em>(discovery)</em></td>
<td>205</td>
<td>30.8</td>
</tr>
<tr>
<td>To have you see for yourself that what we’ve just told you is correct <em>(verification)</em></td>
<td>252</td>
<td>37.9</td>
</tr>
<tr>
<td>To help you get an idea of what being a real scientist is like <em>(real scientist)</em></td>
<td>26</td>
<td>3.9</td>
</tr>
<tr>
<td>To keep you interested in science. Its fun <em>(interesting/fun)</em></td>
<td>33</td>
<td>5.0</td>
</tr>
<tr>
<td>To keep you occupied <em>(occupy you)</em></td>
<td>9</td>
<td>1.4</td>
</tr>
<tr>
<td>Other</td>
<td>42</td>
<td>6.3</td>
</tr>
</tbody>
</table>

*Note: Italics indicate researcher shorthand for the response*
**Question 8: What do you think is your teacher’s opinion of labs?**

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loves them</td>
<td>540</td>
<td>81.2</td>
</tr>
<tr>
<td>Doesn’t like them</td>
<td>5</td>
<td>0.8</td>
</tr>
<tr>
<td>Is afraid of them</td>
<td>7</td>
<td>1.1</td>
</tr>
<tr>
<td>It’s just something we do</td>
<td>108</td>
<td>16.2</td>
</tr>
</tbody>
</table>

**Question 9: About how many labs do you do in a week?**

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 or less per week</td>
<td>273</td>
<td>41.1</td>
</tr>
<tr>
<td>1–2 per week</td>
<td>310</td>
<td>46.6</td>
</tr>
<tr>
<td>more than 2 per week</td>
<td>76</td>
<td>11.4</td>
</tr>
</tbody>
</table>

**Question 10: Do you think you will take a science class in the future (in high school, college, etc)?**

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>432</td>
<td>65.0</td>
</tr>
<tr>
<td>Probably/but I don't want to</td>
<td>180</td>
<td>27.1</td>
</tr>
<tr>
<td>No</td>
<td>47</td>
<td>7.1</td>
</tr>
</tbody>
</table>
Question 11: In general, do you like labs?

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>348</td>
<td>52.3</td>
</tr>
<tr>
<td>No</td>
<td>40</td>
<td>6.0</td>
</tr>
<tr>
<td>Sometimes</td>
<td>270</td>
<td>40.6</td>
</tr>
</tbody>
</table>
Appendix C
Appendix C

Student Data Based on Like or Dislike of Laboratory Experiences

Affective

Fun/Cool (136)
Interesting (41)
Entertaining
Experience the science

Interactive/Engaging
Challenging

Hands-on (96)
Visual (64)

Group work
Up and moving
Self-discovery

Explains/helps the lesson (99)
Application of learning (34)
Proves/tests theory
Applies to career

Easy to get (23)
Remember it well

Not lecture (25)
Nontraditional
Get to experiment
Helps my grade
Procedural issues

Figure 9. Categorization of what students who liked labs liked about them
Figure 10. Categorization of what students who liked labs disliked about them
Figure 11. Categorization of what students who liked labs suggest to improve them
**Figure 12.** Categorization of what students who disliked labs liked about them
Figure 13. Categorization of what students who disliked labs disliked about them
Affective

More interesting
More interaction/
social aspects

More explanation of how lab
applies

More meaningful to
topic
Simpler

Get rid of them/ less labs
Clearer directions
Spend more time

Figure 14. Categorization of what students who disliked labs suggested to improve them
Figure 15. Categorization of what students who sometimes liked labs liked about them
Affective

Not interested in topic (26)
Felt like busy work
Bad partner
Makes me nervous

Don't like making mistakes
Boring (82)
Pointless (54)
Confusing

Don't understand what I'm supposed to learn
Confusing directions (11)
Complicated
Doesn't apply
No review beforehand

Don't like working with gross stuff/chemicals
Not enough time (27)
Lab reports/questions (17)
Math/graphing
Not very hands-on
Didn't work
Too many labs
Procedural issues

Learning Goals

Format

Figure 16. Categorization of what students who sometimes liked labs disliked about them
Figure 17. Categorization of what students who sometimes liked labs suggested to improve them
Appendix D
Appendix D

Interview Outline:

Interview Number:________     Date:_________________

1. Last spring you completed a survey for me on your opinion of laboratory experiences. Did you say you liked, disliked, or sometimes liked laboratory experiences?

   Why:

2. Why do you think we teachers make you do labs?

3. If you liked labs, what do you dislike about them, or if you dislike labs is there anything you like about them?

4. Is there anything labs help you with?

5. I am hearing a lot about students wanting to understand the labs more. What does that mean to you?

6. I know I asked this on your survey, but as you are thinking now, do you have any suggestions to help make lab experiences better?
References
REFERENCES


*Journal of Research in Science Teaching, 6*, 7–86.