SCIENCE LAB REPORT WRITING IN POSTSECONDARY EDUCATION: MEDIATING TEACHING AND LEARNING STRATEGIES BETWEEN STUDENTS AND INSTRUCTORS

by

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A Thesis
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DEDICATION

I dedicate this thesis to my family: Dad, Mom, Lucille, and Carolyn.

To my parents, Tony and Luz Kalaskas, thank you for teaching me the importance of hard work, respect, morals, and discipline. Both of you taught me early on the value of an education, and instilled in me a love for learning that continues to this day. I couldn't have made it this far in life without you both.

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ABSTRACT

SCIENCE LAB REPORT WRITING IN POSTSECONDARY EDUCATION: MEDIATING TEACHING AND LEARNING STRATEGIES BETWEEN STUDENTS AND INSTRUCTORS

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The lab report is a genre commonly assigned by lab instructors and written by science majors in undergraduate science programs. The teaching and learning of the lab report, however, is a complicated and complex process that both instructors and students regularly contend with. This thesis is a qualitative study that aims to mediate the mismatch between students and instructors by ascertaining their attitudes, beliefs, and values regarding lab report writing. In this way, this thesis may suggest changes to teaching and learning strategies that lead to an improvement of lab report writing done by students. Given that little research has been conducted in this area thus far, this thesis also serves as a pilot study. A literature review is first conducted on the history of the lab report to delineate its development since its inception into American postsecondary education in the late 19th century. Genre theory and Vygotsky's zone of proximal development (ZPD) serve as the theoretical lenses for this thesis. Surveys and interviews

are conducted with biology majors and instructors in the Department of Biology at George Mason University. Univariate analysis and coding are applied to elucidate responses from participants. The findings suggest that students may lack the epistemological background to understand lab reports as a process of doing science. This thesis also finds that both instructors and students consider the lab report primarily as a pedagogical genre as opposed to an apprenticeship genre. Additionally, although instructors were found to have utilized an effective piecemeal teaching strategy, there remains a lack of empathy among instructors for students. Collectively, these findings suggest that instructors should modify teaching strategies to determine and address student weaknesses more directly.

Keywords: pilot study, qualitative study, science lab report, postsecondary education

INTRODUCTION

Thinking about lab reports often evokes unpleasant and frustrating memories that I would rather live without. Such are my sentiments when I recall my own experiences doing lab reports as an undergraduate. The routine for doing lab reports was simple, yet challenging. At the conclusion of each experiment, the instructor would assign a lab report that typically ended up being due the following week. Instruction on how to do the report was often general, with basic principles outlined, but nuances and niceties undisclosed. As a result, I'd often find myself questioning the instructor about what I should include in the report. Outside of class, I would collaborate with others on challenges and difficulties I encountered. However, even with my own learning strategy in place, I invariably made at least a few errors. I remember doing relatively well, but never doing well enough to earn a perfect score on any lab report during my undergraduate years. When I examined my reports after grading, I found that instructors often left written comments regarding conceptual errors, inaccurate data, data misinterpretation, formatting, style, grammar, and several other topics. After the reports were returned, I noticed that a few instructors would give a mini lecture about the common errors they found on the lab reports by offering advice on how to prevent those mistakes in the future. For the most part, though, instructors simply returned the reports

and continued with the course schedule with little comment. The process would then repeat itself through the completion of each experiment.

While majoring in biochemistry and biology taught me a significant amount of specialized knowledge, I remain unsure of what they taught me about writing. This is paradoxical given the fact that I did a fair amount of writing through my lab reports. Despite doing so many reports, I couldn't explain their purpose beyond the fact that it was just something people did after they conducted experiments. There was little to no introduction on writing lab reports, and as I advanced in my undergraduate education, I concluded that lab reports were a special type of assignment that some people did better on than others. How else could I explain the fact that instructors spent no time explaining it? By associating lab report writing with an innate ability that inhered only in some students, I misled myself to believe that science was an activity only *some* people could advance in. Such was the case until I took courses in graduate school, which introduced me to the idea of writing-across-the-curriculum, better known as WAC. Through WAC, I learned that there is a place for writing in each and every discipline. However, because writing is often subordinated in order to prioritize content, instructors do not consider it their responsibility to teach the writing that circumscribes their discipline. WAC argues that focus should not be on writing skills per se, but rather "on teaching both the content of the discipline and the particular discourse features used in writing about that content" (McLeod, 2012, p. 54). When I combined my understanding of WAC with my experiences writing lab reports, I realized that there was something lacking in my own undergraduate education. The focus on lab report writing that my undergraduate

instructors supposedly should have had was minimal. Content was emphasized over writing.

Soon after adopting a WAC perspective, I began to see the potential for doing research projects in disciplines across the curriculum, including mathematics, political science, biology, etc. However, given my previous experience as a biochemistry and biology major, I found myself at a significant advantage focusing on science lab reports. Having already taken courses that assign lab reports, I realized that I could anticipate some of the ways in which students learn lab reports and instructors teach them. Additionally, I began supplementing my own perspective by doing a review of the literature. In this way, I formed the central objective of this thesis: to identify ways to improve the teaching and learning of the lab report by addressing the mismatch between instructors and students. In this thesis, I directly question the students who write the reports and the instructors who read them in order to ascertain ways to improve the lab report as a teaching and learning tool. As I read through the literature, I found that biology, chemistry, and physics constituted the traditional science disciplines having been established with the advent of the modern university model (Lerner, 2007; Russell, 2002). In the following chapter, I delineate the significance of disciplines and the modern university. For now, though, I identify biology as the discipline on which I base my study, and the Department of Biology at George Mason University (GMU) as the location for which my study takes place. Given the biology department's participation in GMU's WAC program, I found the conditions amenable to pursue a study of lab reports. By integrating WAC into its curriculum, the biology department indicated that it was

already interested in the role of writing in its discipline. Receptiveness of the community, therefore, appears to be a central prerequisite to the initiation of my study.

Although I cover the history of lab reports in the following chapter, I wish to provide some initial context on what I mean by lab reports done in the college setting. Lobban and Schefter (1992) have defined a lab report as a paper structured through the IMRAD formula: Introduction, Materials and Methods, Results, and Discussion (pp. 4-6). Additional sections that are not specifically mentioned in the IMRAD acronym include the Abstract, References, and Figures and Tables (Lobban & Schefter, 1992, pp. 4-6). Each of the four main sections in the IMRAD formula has a particular purpose, and is often described and outlined in course laboratory manuals (see Appendix A for example). For examples of lab reports written by students, see Appendices B and C. Given its relatively simple IMRAD structure, the process of doing lab reports would appear ostensibly clear and straightforward: Instructions are provided and students follow them to meet the expectations of the instructor. However, such notions would constitute a gross oversimplification of the reality that exists between instructors and students. Although lab reports are presented as formal, organized, and immaculate documents, the process by which they are produced is informal, recursive, complex, and uncertain. Rather than examine the lab reports themselves, my study focuses on the writers and readers of such reports. My thesis aims to uncover the attitudes, beliefs, and values that instructors and students have regarding lab reports in order to improve teaching and learning strategies.

In the first chapter, I present my literature review, which describes relevant background research on lab report writing in the academic setting. The literature review provides the foundation on which I frame my study, and the means by which I articulate my thesis' problem, context, questions, and theories. In chapter two, I describe the methods by stipulating the data collection methods, data sources, and data analysis methods. In chapter three, I present the results, which include the qualitative data that I obtained. This thesis ends with chapter four, the discussion. In that section, I draw conclusions from my data and make suggestions on teaching and learning strategies. Based on the organization of my thesis, readers may have noticed that it is also formulated on IMRAD. In this way, I also show that the IMRAD structure is not exclusive to the pure sciences since experiments can also be conducted in the social sciences.

CHAPTER 1: LITERATURE REVIEW

This chapter is divided into the following sections: historical and institutional context, contemporary pedagogical practices, problems and research questions, theoretical triangulation, and hypotheses. By doing so, I provide a comprehensive overview of the lab report across time and space in institutions of higher learning. The order that I introduce each topic is significant since each preceding section serves as a foundation for the next. By citing studies that address the lab report, I give voice to the relevant experiences that guide the course of my own study. The purpose of this section is to introduce the lab report with a marked focus on how it has developed over time, how it is taught today, and what its current perspectives and perceptions are. Such a focus attempts to resolve the first of my research questions that serves as a precursor for the rest of my study: *What is the undergraduate science lab report? And how has it developed over time?*

Historical and Institutional Context

In this section, I provide a broad overview of the lab report's historical development since its importation into American postsecondary education in the latter half of the 19th century. Additionally, I frame the lab report as an academic derivation of the professional activity of the science discipline and elaborate on the ensuing conflicts that resulted and continue to this day. Finally, I examine the advent of writing-across-

the-curriculum (WAC) and how its philosophy in higher education has altered the course of lab report writing since the 1970s.

American inception and early years.

Determining the origins of lab reports written at the undergraduate level in the United States requires a synchronous discussion of the origins of what Russell (2002) has termed, the *modern university*. Russell (2002) has defined the modern university as a "compartmentalized, additive structure" with "specialized disciplinary communities organized by written discourse" (p. 55). Russell (2002) further listed three critical components of the modern university: "(a) research orientation, (b) specialized elective curriculum, and (c) insular departmental structure" (p. 268). Its growth and spread became evident following the United States Civil War, markedly between the 1870s and 1900s when "a chorus of voices from around the nation cried out for colleges and academies to become 'more practical,' to give up their rigid classicism and elitism" (Russell, 2002, p. 46). Such pleas facilitated the formation and development of the modern university. Of critical importance, though, is stipulating where this type of university came from and why it was so conducive to forming the lab reports students and instructors learn and teach today.

According to Russell (2002), the idea for a modern university was imported from Germany, in which "faculty supervised apprentice researchers in the discipline" (p. 48). In the sciences, this meant the creation of a new pedagogical site for writing, the *laboratory*, and the genre of student writing associated with it, the *laboratory report* (Russell, 2002, p. 71). Indeed, the laboratory and laboratory report were part and parcel

of the scientific specialized disciplinary communities that comprised the modern university. Russell (2002) further elaborated that the faculty who espoused the "German-inspired ethic of free scientific research….upheld the ideal of unfettered inquiry as the institution's fundamental reason for being, a positive good, which sensible students would willingly, independently pursue (as the faculty had and did)" through a "master-apprentice relationship" (p. 71).

Such notions of a master-apprentice relationship in undergraduate science laboratories were short-lived, though, as indicated by the nature of lab report writing assigned in those courses. Lerner (2007) has argued that even with the burgeoning of laboratories in the 1890s and 1900s, students were not being inculcated into the complex rhetorical practices of professional scientists (p. 198). While students were supposedly conducting experiments and writing lab reports, these activities did not reflect the work of real scientists since the rhetorical situation was reduced to an exercise of *verification*, in which students were tasked with verifying the facts and principles they had learned in lecture and recitation (Russell, 2002, p. 93). Similarly, Lerner (2007) indicated that "students were writing or drawing to readers or examiners who would offer little written feedback and merely check to see how well students could render the content that had been passed along through lectures or textbooks" (p. 198). Through these pedagogical practices, Russell (2002) concluded that the sciences at modern universities were isolating and separating "writing in school and college laboratories from the activity of science" (p. 93). Evidently, lab reports in the 1890s "were shaped in the image of other

school writing: routine, mechanically correct, primarily evaluative" (Russell, 2002, p. 93).

Factors that were attributed to the detraction of the lab report include the following: (a) too few labs were available to accommodate the exponentially growing college student populations; (b) class sizes were too large; (c) "faculty employed lab assistants, who tended to standardize and make routine the instruction;" and (d) lab notebooks supplanted lab reports as a means of evaluation, with a focus on "neatness and precision rather than for their utility in the lab or beyond" (Russell, 2002, p. 94). Lerner (2007) illustrated the continuation of this trend by describing a lab report written by an undergraduate attending Amherst in 1924. In his examination, Lerner (2007) explained that "this short-answer template shows little evidence of reasoning, problem solving, or creativity. Instruction in report writing never moved much beyond the minimalist prose of fill-in-the-blank worksheets or the assertion that good writing equals correct writing" (p. 200). Indeed, the 1920s and 1930s marked an era in which lab reports were reduced to fill-in-the-blank exercises (Russell, 2002, p. 248).

Both Lerner (2007) and Russell (2002) used the term, *cookbook*, to describe labs in which students wrote reports as a result of following a preconceived set of instructions, analogous to a recipe, in which their goal was to find the correct answer. It appears that the terms, cookbook and verification, indicate types of experiments and lab reports that are separated from the real work and activity of professional scientists. According to this perspective, lab reports have evolved from their original purpose. Instead of being the means by which to prepare students for professional careers as expert scientists working

in the discipline, they were reduced to a decontextualized learning tool utilized to teach scientific content (Lerner, 2007, pp. 216-217). Such an assumption, though, implies a relative phenomenon, in which lab reports did not evolve per se, but rather were derived from a professional form of the genre known as the *experimental article* or *scientific paper*. In other words, the lab report is a derivative of the experimental article and not a creation in and of itself.

Disciplinary derivation.

An understanding of the term, *discipline*, is a prerequisite when tracing how and why the lab report was derived from the experimental article. Russell (2002) has described the discipline as "the organizing principle of knowledge" manifested as departments to bring physical order and organization to educational institutions (p. 47). Russell (2002) further stipulated that "the modern academic disciplines" formed discrete "conventions of discourse," such as "professional meetings, seminars, journals, books…scholarly discourse.…terminology, methods, rules of evidence, standards of scholarly presentation and documentation" (p. 47). By this nature, a discipline reflects a body of *specialized knowledge* commanded by insiders, who in the academic setting would be professors taking on the role of researcher. Langer (1992) has extended the definition of discipline to suggest its epistemological assumptions, in which the *ways of knowing* circumscribe one discipline from another. Indeed, these ways of knowing are implied through fundamental disciplinary concepts: "(a) notions of causality and proof, (b) of evidence or warrants for claims, (c) of assumptions that can be taken for granted, and (d) of premises that must be made explicit and defended" (Langer, 1992, p. 71).

Langer (1992) has noted that students of science "write reports about specific events, for example, and also write *analyses* based on their observations," which are intended to reflect, or at least imitate the aforementioned "fundamental disciplinary concepts" (p. 71). The connection then becomes clear: instructors assign writing that is typical of the activity in their discipline. Thaiss and Zawacki (2006) have demonstrated in their ethnographic study of college students and instructors that an instructor's discipline plays a significant role in determining the nature of writing assignments given to students. Interviews with college instructors and a review of teaching materials indicated "clear connections between a faculty member's priorities in scholarship and priorities in teaching" (Thaiss & Zawacki, 2006, p. 146). However, Bazerman (1994b) has qualified this influence by asserting that some teachers apply a pedagogical theory, called "*formal textualized reduction* [emphasis added], requiring student enactment of well-defined genres, clearly distinct from the genres that come from outside the classroom" (p. 29). In other words, even though the disciplinary interests of instructors determine the type of writing assignments given to students, those writing assignments may not reflect actual disciplinary practice. Through this pedagogical practice, Russell (2002) has intimated that disciplines engage in this approach because they are continually seeking to initiate "new members into the discourse of their communities" (p. 20) to as Bazerman (1988) indicated, create knowledge. Essentially, a discipline survives by inculcating students at modern universities.

The impact of formal textualized reduction is significant because it provides the basis upon which lab reports become differentiated from its professional genre, the

experimental report. In this way, the science discipline plays a significant role in determining its function and structure. Bazerman (1988) has evinced that the discipline's professional form, the experimental report, has existed in "the natural sciences" for "the last three centuries" (p. 7). Further, Bazerman (1988) has stated that "the experimental report has developed as a favored solution of the problem of how to present empirical experience as more than brute fact, as a mediated statement of inquiry and knowledge" (p. 7). In this way, Bazerman (1988) intimated the *scientific method*, the guiding principle of science that leads to the formation of knowledge through systematic investigation. Namely, the scientific method refers to the "principles and procedures for the systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of hypotheses" (*Merriam-Webster's online dictionary*, 2013).

Such a description echoes the claims of Lerner (2007) and Russell (2002), in which they declared that the original purpose of bringing lab reports into the science lab classroom was to prepare students to act, think, and write like real scientists. Accordingly, teaching the scientific method was the means by which to accomplish that goal. However, the reality remains much closer to the practice of formal textualized reduction stipulated by Bazerman (1994b). To elucidate this context further, it appears that the experimental report is the archetype of the lab report. Additionally, the *experimental article* and *lab report* refer to different contexts, the former to a professional setting and the latter to the school setting. While related and similar, they hold different purposes, writers, and audiences. Further, Thaiss and Zawacki (2006) have

suggested that the nature of the science discipline makes them *compact*, or closely tied together, since the lab reports that students write are modeled on the generic template of the experimental report, IMRAD, which serves as the disciplinary standard (pp. 14-15).

So, while the lab report, "in origin and principle," was "tied both to the research activity of the discipline and to its pedagogy," it did not lead to the myriad of professional scientists as first anticipated (Russell, 2002, p. 98). Instead, the space between what it meant to be a professional scientist and what it meant to be an undergraduate science major grew. Russell (2002) expressed that from the 1920s to the present, discussions among expert scientists "became highly theoretical and quantitative, filled with technical terms understandable only to small subcommunities of specialists playing a narrow professional role," hence diverging students further from instructors (p. 248). Yore, Hand, and Prain (2002) have conducted a qualitative study in which they corroborated Bazerman's (1988) claim that the writing done by expert scientists was meant to create knowledge. Based on survey responses from professional scientists, Yore et al. (2002) determined that expert scientists could "build knowledge and help construct understanding" through their experimental reports, which adhered to the scientific method (p. 689). Yore et al. (2002) further stipulated that for scientists, writing was an "interactive, recursive, and dynamic process in which the purpose and the target audience [other expert scientists]…influenced the writing act" (Yore, Hand, & Prain, 2002, p. 689).

Compared to the activity of expert scientists, undergraduate science majors do not fully participate in the discipline like their instructors, who have taken the de facto role of

expert scientists in the modern university. Berkenkotter and Huckin (1993) have contended that the lab report is a type of *institutional*, *curriculum*, or *pedagogical* genre since it contains "*some* of the textual features and *some* of the conventions of disciplinary genres [e.g., the experimental report] but that they are also linked to and instantiate classroom-based activities such as…conducting simple experiments of the kind found in lab manuals," which consequently result in students writing up decontextualized lab reports (pp. 487-488). Again, such insight evokes Lerner's (2007) and Russell's (2002) observation that lab reports have merely become exercises in verification, or confirming the correct answer. Indeed, if anything, the lab report had taken a subordinate role to the experimental article in the discipline. However, given the rise of the writing-across-the-curriculum (WAC) movement in the latter decades of the 20th century, various attempts were made to make the lab report relevant and significant for both students and instructors by connecting it in a meaningful way to the science disciplines at modern universities.

Advent of WAC.

According to Russell (2002), the WAC movement began in the 1970s out of a "perceived need for greater access, greater equity.…to assimilate, integrate, or (in the current phrasing) initiate previously excluded students by means of language instruction" (p. 271). The movement's aim was to make the disciplines at modern universities more accessible and open to students through writing. The effects of WAC were significant since it sparked an interest in writing among the disciplines that endures to the present. Russell (2002) has enumerated the development during the incipient years of WAC: "(a)

faculty development workshops, (b) a faculty wide supervisory committee, (c) a writing lab with a writing specialist as coordinator, (d) student tutors, (e) departmental responsibility for students' writing proficiency, (f) a system of student writing portfolios, and (g) external funding (federal and corporate) to defray start-up costs" (p. 283). However, even with departmental restructuring of resources, the WAC movement at that moment in time still lacked a guiding philosophy that addressed the differentiated structure of the modern university. Until then, writing remained subordinate to disciplinary interests, and so did the lab report.

The new philosophy encouraged science disciplines at modern universities to contemplate how and why their students write lab reports in the first place. The WAC movement achieved this by articulating that the discipline had to understand its own rhetorical situation. Bazerman (1992) has written that "*rhetorical analysis* [emphasis added] can make visible the complexity of participation by many people to maintain the large projects of the disciplines" (p. 64). This implies that addressing the rhetorical situation makes linking the discipline to the classroom, which is considered a large project of the discipline, both possible and constructive. With respect to the classroom, Bazerman (1994b) astutely noted the dynamic features of its rhetorical situation by realizing that it was not a "particular fixed scene, but many scenes" that set "in motion expectancies of role and behavior as well as possibilities for statement and action," as well as "genres of communication, genres of ways of being in that setting" (p. 26). In other words, disciplines should consider that the work done in the classroom is commensurate to the work done in the discipline itself, both being contextualized and

authentic. By extrapolation, it would appear then that the lab report writing done in the classroom laboratory by students would hold disciplinary value as well. In this way, analyzing the rhetorical situation of disciplines became a central part of the foundation that determined the WAC philosophy within modern universities.

Russell (2002) has indicated that WAC may be able to achieve its ultimate goal of reforming American pedagogy if it convinces disciplines to "assume responsibility for making writing a central part of their pedagogy" (p. 302). In this way, the means by which to connect the discipline to the classroom is through the writing that instructors assign their students to do. Russell (2002) understood the connection that WAC espoused with respect to the disciplines, the classroom, and writing in the following way:

> If writing is to become a central focus of pedagogy, then it must be structurally linked to the values, goals, and activities of disciplines; faculty must see a connection between encouraging better writing among their students and advancing the value and status of their disciplines—and of their own individual careers. Disciplines must find or create places where student writing matters to the disciplinary community. (p. 302)

Applying WAC philosophy to higher education opened the door to research and pedagogical practices that placed specific focus on the kinds of writing found in the disciplines. The science disciplines and the lab report, of course, were no exception. In the following section, I delineate the pedagogical impact of WAC on the teaching of lab report writing in the science disciplines.

Contemporary Pedagogical Practices

Since the inception of the WAC movement in the 1970s, a variety of pedagogical practices have developed as a result of the movement's influence. In this section, I place a marked focus on the effects that WAC has had on lab report writing in the science disciplines. I begin by examining pedagogical practices on lab report writing that have emerged since the 1970s, and end by discussing studies influenced by WAC that attempt to ascertain student and teacher perceptions regarding lab report writing.

1970s: Aiming for context and grading.

The interest in lab report writing sparked by WAC engendered a wave of action research whose studies have become evident in educational journals since the 1970s. By action research, I mean research conducted by instructors on their students with respect to their teaching practices (see Stringer, 2008, for discussion). In such cases, instructors attempted to identify common errors made by students on lab reports and develop practices that aimed to prevent them. For example, as early as 1977, Alan A. Gubanich, who at the time was director of general biology at the University of Nevada, Reno, had documented a list of fifteen common mistakes on lab reports made by his students (Gubanich, 1977, p. 27). Gubanich (1977) postulated that "for most beginning students…writing a scientific paper is a new and foreign experience" (p. 27). Apparently, Gubanich (1977) taught an *investigative laboratory approach,* in which students conducted individual research projects on topics of their own choosing, and wrote a report at the end of the semester (p. 27). Surprisingly, such an approach contrasts

markedly with the cookbook style reports that Lerner (2007) and Russell (2002) criticized for being inauthentic and decontextualized.

However, the 1970s also marked the rise of the instructor's assumption that lab reports become the means by which to assign student grades. Pickering and Goldstein (1977) have indicated that in a "traditional lab report based grading system, the lab report grades determined 40% of the course grade" (p. 316). Pickering and Goldstein (1977) further stated that "all reports were graded piecemeal and assembly line fashion by the TA's" (p. 316). The divergent views of Gubanich (1977) and Pickering and Goldstein (1977) demonstrate the polar views of lab reports within the context of the university, where the former wishes to encourage students to enter the discipline and the latter assesses and ranks students based on how well the lab reports prepared students for content knowledge exams.

1980s: Feedback, commentary, and the writing task.

In the 1980s, Brillhart and Debs (1981) anticipated Bazerman's (1992) call for integrating disciplinary writing into the classroom in a meaningful way. Brillhart and Debs (1981) have observed that "most schools have stopped requiring formal lab reports and have replaced them with 'fill-in-the-blank' and short-answer formats" (p. 303). Consequently, Brillhart and Debs (1981) have condemned such practices arguing that "by the nature of their discipline…science teachers are responsible for introducing students to the processes of data collection and utilization" (p. 303). Brillhart and Debs (1981) insisted that students could learn how to do lab reports when "writing is taught…by evaluating written lab reports, by editing, by critical grading of the things that students

write" (p. 303). Unlike Pickering and Goldstein (1977), Brillhart and Debs (1981) appear to use grading as an opportunity to provide feedback and commentary that are intended to encourage students to adopt disciplinary ways of thinking and writing. Using this approach, Brillhart and Debs (1981) have advocated a *process-based* approach to teach lab report writing in which the instructor *scaffolds*, or provides significant assistance at the beginning of the course, and gradually tapers assistance over time. So, for example, at the beginning of the course, "a completed model lab report" is "handed out and discussed in detail" (Brillhart & Debs, 1981, p. 303). Like Gubanich (1977), Brillhart and Debs (1981) acknowledge that their "students have had very little experience writing formal lab reports," and consequently require detailed instructions that make expectations clear (p. 303).

At Santa Clara University in the mid-1980s, a particularly engaging strategy developed that applied concepts derived from WAC. In this practice, Rosenthal (1987) attempted to relate modern composition pedagogy to lab report writing. Rosenthal (1987) categorized the sections of a lab report based on the *cognitive level* of a writing task. So, for example, "*classification*, *summary*, and *compare/contrast*" constituted medium level tasks indicative of the methods section, whereas "*analysis* and *argument*" constituted high level tasks indicative of the discussion section (Rosenthal, 1987, p. 997). The main aim of this approach appears to be clarifying goals and expectations for lab reports since students lacked experience writing them. Rosenthal (1987) has written:

> One of the goals of any educator is to ensure, as fully as possible, that students have at least functional ability at high cognitive level tasks by the time they

> graduate. From the perspective of science, these are tasks in drawing conclusions from data. We hope to teach our students, first of all, to draw reasonable, valid conclusions from data, and second to articulate the reasoning process clearly so that a cogent argument is presented. (p. 997)

By analyzing the lab report and explaining what information should go in each section, Rosenthal (1987) enriched the learning experience of students. In the 1980s, the WAC movement encouraged instructors to take a closer look at themselves relative to their students. The trend of making lab report instruction explicit, specific, and contextualized makes evident an attempt to articulate the discipline to students.

1990s: Integrating the discipline.

The beginning of the 1990s presented an even more ambitious attempt by instructors to integrate the discipline into the classroom laboratory. At Michigan Technological University, Gratz (1990) proposed a pedagogical practice that allows students to engage in activities that are similar to those of expert scientists when writing lab reports. Gratz (1990) acknowledged that "lab report writing is a mechanism for preparing students to write scientific papers" (p. 293). In this way, Gratz (1990) had an understanding of the rhetorical divergence that separated the lab report from the disciplinary activity of real scientists. After attending a WAC workshop in 1979, Gratz (1990) formed and implemented teaching practices on lab reports that conformed to disciplinary practice. Gratz (1990) espoused a pedagogical practice that was sequenced in the following way: (a) model analysis, in which students wrote their lab reports in the style of published experimental articles they had read previously in the semester; (b) peer

review, in which classmates used analysis sheets prepared by the instructor to assess each other's lab reports; and (c) revision, in which students reexamined their reports by taking into account comments from the peer review (p. 294). Essentially, Gratz (1990) was attempting to relate the discipline to his teaching by integrating elements that reflected its professional practice. For example, Gratz (1990) explained that "the use of published papers rather than model lab reports for analysis is preferred since the students see that they are learning to write as professional scientists write" (p. 295).

Koprowski (1997) later conducted action research on his own undergraduate lab students at Willamette University by attempting to ascertain the value of peer review in the lab report writing process. Unlike Gratz (1990), Koprowski (1997) focused on the effect that a peer review conducted in a double-blind fashion would have on students. Under those conditions, each student's lab report was given a pseudonym to conceal the identity of the author so that students were unaware of who was grading whose paper. Based on survey results requesting student feedback on the peer review process, Koprowski (1997) found overwhelming support for the peer review method with respect to lab report writing. Specifically, he found that "the assignment [peer review] appears to empower students by increasing their sense of ownership of the review process and exposing them to a 'professional' experience" (Koprowski, 1997, p. 135).

2000s: Technology, process, and structure.

Even more significant progress was made as WAC crossed into the 21st century. Russell (2002) asserted that "one of the most promising developments in WAC in the 1990s is computer-aided writing instruction for specific disciplines" (p. 325). The

development of such instruction made significant headway in the 2000s. Given the support of National Science Foundation grants, instructors at North Carolina State University created *LabWrite*, a web-based effort to teach lab report writing online in support of science lab courses. LabWrite accomplished this task by providing "students with sophisticated heuristics and other direct instruction for writing laboratory reports, transforming what is often a 'cook-book' classroom genre that requires little thinking beyond following instructions into a way of teaching the structure of scientific thinking and argument" (Russell, 2002, p. 326). In 2004, Carter, Ferzli, and Wiebe, the creators and designers of LabWrite, explained the assumptions underlying their approach to teaching lab reports. Carter et al. (2004) indicated that the lab report constituted a *genre set*, in which individual genres are temporally and interdependently related (p. 399). Succinctly, a genre set or system of genre is "interrelated genres that interact with each other in specific settings" (Bazerman, 1994a, p. 97). Carter et al. (2004) stipulated that the lab report was a process that began even before the actual writing of the report that was to be turned in. In this way, they found that the lab report consists of the following:

- formal discussions of upcoming labs at meetings of lab instructors,
- a lab manual,
- a one- or two- page description of the elements of the lab report,
- a brief lecture or announcements by lab instructors at the beginning of lab,
- a lab handout sometimes given to students before starting the experiment,
- a pre-lab questionnaire,
- a lab notebook,

- digital spreadsheets for data,
- formal tables and graphs and other figures,
- lab reports handed in to instructor,
- answer keys used by instructors to grade reports, and
- graded lab reports returned to students (Carter, Ferzli, & Wiebe, 2004, p. 399).

By interpreting the lab report not simply as an isolated act of discourse, but instead as a dynamic interrelated arrangement of different genres, Carter et al. (2004) developed online instructional materials that addressed the various skill levels of students. Carter et al. (2004) have stated that LabWrite is "organized as a chronological process paralleling the lab activities" (p. 400). Namely, they have scaffolded the process of writing a lab report by providing online instructional material that focuses on the following: (a) Pre-Lab, a set of questions that students do before lab to initiate scientific understanding of the experiment and its relevance to scientific concepts; (b) In-Lab, guides that assist students during lab on collecting and organizing data; (c) Post-Lab, guide to composing the lab report; and (d) LabCheck, a heuristic and rubric that facilitates revision of the lab report before it is turned in to the instructor (Carter et al., 2004, p. 400). In this comprehensive practice, Carter et al. (2004) have extended the ability of instructors to specifically and explicitly instruct students on lab report writing. By breaking the lab report into manageable pieces and indicating the roles that each piece represents, LabWrite has articulated the rhetorical nature of the laboratory classroom. Additionally, Carter et al. (2004) have demonstrated the efficacy of online instructional tools in the teaching of lab report writing.

While LabWrite may represent the most ambitious expansion of the teaching of lab report writing yet, other practices have continued to develop in the new century. Cacciatore and Sevian (2006) developed a teaching practice in which they markedly stressed the importance of communication and collaboration in the science laboratory. At the start of lab, different pairs of students were given one of three sample lab reports written by previous students; each sample was missing one of the following: materials and methods, results, or discussion. According to Cacciatore and Sevian (2006), students had to complete the missing section they were given without showing each other their lab reports. As a result, Cacciatore and Sevian (2006) observed that there was more student-student interaction and more importantly, a greater understanding by students of how interdependent the parts of a lab report are. For example, Cacciatore and Sevian (2006) had noted that through this practice, students now "understood why lab reports had to contain so much information and why the information had to be organized in similar format in all reports" (p. 1040). This approach had essentially allowed students to communicate like scientists in the laboratory, as well as read and write like scientists by realizing the genre's expectations of the IMRAD format. In other words, students began to understand that scientists have certain expectations when they read a lab report, namely, a format that adheres to disciplinary principles.

In recent years, pedagogical advances have been made which continue to promote WAC's student-centered approach. At the University of Victoria and Vancouver Island University, both in Canada, Berry and Fawkes (2010) have implemented teaching practices intended to focus on the sections of the lab report. Berry and Fawkes (2010)

asserted that their teaching practice applied a "*piecemeal approach* [emphasis added], peer review, and a limited draft option" (p. 57). In the piecemeal approach, Berry and Fawkes (2010) apportioned the work of the lab and lab report through a period of weeks, requiring that students turn in certain sections of the lab report after completing certain parts of the experiment (p. 58). In between turn-in dates of lab report sections, students also received ungraded photocopies that they were assigned to review. In this case, peer reviews served a different purpose to the aforementioned studies since students did not give their feedback back to other students, but instead to the teacher. However, since sections of the lab report were graded in piecemeal before the final and entire report was due, students were given opportunities to revise according to instructor commentary provided on the reports. When Berry and Fawkes (2010) garnered student responses via a survey regarding this teaching practice, they found that students were especially appreciative of the chance to focus on small sections [of the lab report] at a time since they lacked experience writing lab reports (p. 59).

Given the advent of new pedagogical practices influenced by WAC, new WAC studies also emerged that endeavored to articulate exactly what the lab report was. In the following section, I examine and describe those findings.

Perspectives and perceptions.

Recently, Carter (2007) has described lab report writing as a *way of writing* in the disciplines that is related to a *way of knowing* and *way of doing*. From this perspective, he has tied lab report writing to the act of doing an experiment and the process of learning knowledge. Similarly, Braine (1989) has specified that the lab report was a

"*report on a specified participatory experience*" (p. 7). By relating the lab report to the action on which it is based, it becomes increasingly clear that context plays an important role. Carter (2007) found the following:

> Thus, the lab experience is a way of doing that is directed toward a way of knowing. It is primarily in writing the lab report, however, that doing becomes knowing. More than merely evidence of having completed the lab and having found the right answers, the lab report frames the doing as a scientific way of knowing: introduction, methods, results, discussion; establishing a hypothesis, testing the hypothesis, accumulating evidence related to the hypothesis, determining whether or not the hypothesis is accepted and why. It provides an opportunity for students to reflect on the relationship between the lab and the scientific concept of the lab and to frame the doing of the lab in the structure of scientific reasoning. (p. 388)

In a way, Carter's (2007) analysis describes the scientific method mentioned previously. Given students' relative newcomer status in the discipline, they may perceive that they truly are engaging in a process of authentic discovery, of real ways of knowing the discipline. Since the lab report connects action to cognitive and writing abilities, it may be fair to claim that it encompasses all three: the knowing, the doing, and the writing.

In order to corroborate such claims, Carter, Ferzli, and Wiebe (2007), interviewed 10 students enrolled in Biology 183, a lab course, at North Carolina State University. During the interviews, they inquired about "students' current and past experiences with lab reports, their processes for writing lab reports, their attitudes toward the report, and

their views about the role of the report" (Carter, Ferzli, & Wiebe, 2007, p. 285). Student responses suggested that the lab report is not as divorced from the discipline as Lerner (2007) and Russell (2002) had previously asserted. As a result of student interviews, Carter et al. (2007) claimed that it is the similarities between the lab report and the scientific journal article that "makes the lab report a legitimate apprenticeship genre: They share the structure of introduction, methods, results, and discussion, representing a shared way of knowing that is mirrored in other professional scientific genres" (p. 294). Elaborating on the role of lab reports as an apprenticeship genre, Carter et al. (2007) found that "lab reports appear to encourage *socialization* [emphasis added] into the community of science. That is, they are a way of doing by which students participate in the ways of knowing of that community" (p. 295). Student responses suggested that by doing experiments and writing lab reports, they were participating in the activities of the discipline and therefore connecting with the scientific community (Carter et al., 2007, p. 296). Unlike traditional school genres, which are exercises given for the sake of grading, students saw the lab report "as a stake in their discipline, a link to a community of practice beyond their Biology 183 lab" (Carter et al., 2007, p. 297). What Carter et al.'s (2007) study appears to have done is place focus on the students in order to determine what they think of the lab report.

However, studies that focus only on lab report writing, such as Carter et al.'s (2007) are extremely rare. In fact, the 2007 study by Carter et al. is the only study that I found which gives such a targeted focus. At the same time, though, other WAC studies have been conducted, which attempt to gain an overall sense of writing among the

various disciplines. Those studies provide relevant perspectives from students and teachers regarding disciplinary writing, such as the lab report. In one such study, Hilgers, Hussey, and Stitt-Bergh (2012), interviewed 34 students at the University of Hawai'i in order to ascertain their attitudes toward writing. Hilgers et al. (2012) found that students thought of their writing tasks as

- a content-driven problem,
- a window into a discipline's methodology,
- was shaped by audience expectations,
- an opportunity to pursue personal goals, and
- a preparation for postcollege employment (pp. 268-274).

Particularly striking was a response by a chemistry major regarding lab report writing and the workplace. This student had said, "If I was to be a chemist, I would need to write reports [lab reports] and my reports would be similar to these [college lab reports]" (Hilgers, Hussey, & Stitt-Bergh, 2012, p. 273). At the same time, though, students implied their awareness of the limitations of their rhetorical situation. For example, one chemistry major had stated, "The first [lab report] that I had written was more a specialized genre like for a symposium. I got shot down for that. I got smart and next I asked the TA what it was that he wanted me to write about. So now I know basically what he *expects* [emphasis added]" (Hilgers et al., 2012, p. 270). The differing perspectives between these chemistry majors indicate that the purpose of lab report writing is not always so clear. While thought of as a means to prepare for the disciplinary workplace, it also must meet the expectations of the instructor. Previous literature that I

have cited, such as Berkenkotter and Huckin (1993), have suggested that it is for this exact reason that lab report writing does not constitute an apprenticeship genre. The lab reports done in school serve a different audience, context, and purpose than that of the disciplinary workplace.

However, another recent WAC study has qualified the contention of Berkenkotter and Huckin (1993). At George Mason University, Thaiss and Zawacki (2006) conducted surveys and interviews with instructors and students across the disciplines in order to ascertain their attitudes about writing as well. Their results appear to corroborate Hilgers et al. (2012) when they found that their student informants could distinguish "between writing for teachers and writing for other audiences, including audiences that they imagine as part of their writing goals in the discipline" (Thaiss & Zawacki, 2006, p. 102). Additionally, Thaiss and Zawacki (2006) have postulated that a student doing writing assigned by instructors in the disciplines is commensurate to doing disciplinary writing itself. Since students look to instructor expectations to fulfill assignments, and since those expectations are embedded within the discipline, it must also be true that students are engaging the very same disciplinary interests of their instructors through their writing (Thaiss and Zawacki, 2006, p. 122). Taken this way, when students write lab reports, they are engaging in the activities of the science discipline just as Carter (2007) and Carter et al. (2007) had asserted. Thaiss and Zawacki (2006) have adduced that an environmental science professor's "primary rhetorical concern for undergraduate majors in biology and environmental science is that they learn the genre of the experimental lab

report—according with his primary epistemological goal that they learn the methods of scientific observation and analysis [the scientific method]" (p. 63).

Haas (1994), however, has suggested that the primary rhetorical concern for undergraduate majors should be the context by which they find themselves relative to the discipline. In other words, the students' role as a fledgling in the discipline matters more. In a longitudinal study, Haas (1994) followed Eliza, a biology major, for four years of undergraduate education, and found that *reading* was a central way of initiating Eliza into the biological sciences discipline. Once Eliza saw the authors of scientific journal articles "as *writers* [emphasis added] and as scientists" with motives and circumstances that were the "product of a particular, historical time," she began to see why scientists wrote the way they did (Haas, 1994, p. 65). Haas (1994) has intimated that when students understand the disciplinary motivations of scientists, they too can comprehend why writing a lab report is a way of learning the activities of a discipline. Similarly, Gillen (2006) has suggested that this learning process can work in reverse as well by suggesting that by writing lab reports, students gain an understanding of scientific journal articles (p. 35). Therefore, it appears that the learning of lab reports and scientific journal articles can be bidirectional and reciprocal with each aiding in the insight of the other.

Problems and Research Questions

So far, this review of the literature has focused on the history of the lab report by establishing its context and role in American postsecondary education. Additionally, it has reported on the various ways it is taught by instructors and perceived by students in the sciences. Through this review of the literature, three problems become quite clear.

First, there appears to be conflicting points of view with respect to the purpose of the lab report. Berkenkotter and Huckin (1993) have maintained that the lab report constitutes a genre that is divorced from the authentic activity of the science discipline. Carter (2007), Carter et al. (2007), Thaiss and Zawacki (2006), and most of the instructors described in the section on pedagogical practices have described the lab report as commensurate to the authentic activity of the science discipline.

Second, up to this point, relatively few studies have been conducted that focus solely on lab report writing done by undergraduates. Carter (2007), Carter et al. (2004), and Carter et al. (2007) constitute the few salient examples of studies breaking ground on lab report writing at the college level. Third, and most importantly, no research has focused on the *mismatch* between how students and instructors perceive the lab report. I consider this to be the most paramount problem since it actually synthesizes the preceding two problems in the context of how they affect students and instructors. In this way, the conflicting pedagogical and apprenticeship perspectives may explain why instructors and students perceive the lab report differently. Therefore, I cast the mismatch between students and instructors as the central problem of this thesis, and query the following two research questions accordingly:

(1) *What are the attitudes, beliefs, and values of instructors regarding lab report writing? Why is that the case?*

(2) *What are the attitudes, beliefs, and values of students regarding lab report writing? Why is that the case?*

By focusing on the instructors and students who teach and learn the lab report, this thesis aims to conduct research in an area that heretofore has raised conflicting perspectives and not been investigated yet by most of the research community. To answer these two research questions, I utilize two theories that are aimed at addressing the relationship between students and instructors with respect to lab report writing.

Theoretical Triangulation

Denzin (1978) has defined theory triangulation as the use of "multiple rather than single perspectives in relation to the same set of objects" (p. 295). The theories I have selected are genre theory and Vygotsky's zone of proximal development (ZPD) since they relate to the social action of the lab report, and hence provide possible insight into students' and instructors' attitudes, beliefs, and values. My review of the literature has revealed that genre theory appears to be the predominant theory applied to lab report writing. Thus far, ZPD has not been considered in the study of lab report writing. This thesis aims to enrich the current literature by directing genre theory and ZPD to address the mismatch of perceptions between students and instructors. I consider such an approach appropriate for this thesis given the various perspectives that I found in my review of the literature. With more than one perspective and hypothesis in mind, I have the added advantage of addressing alternative interpretations that I may improperly dismiss if I only apply a single theory. In the next chapter on methods, I will explain how I use theoretical triangulation to interpret the empirical data that I collect in my study. For now, I explicate each of the theories below in order to establish a context on which my theoretical framework is built.

Genre theory.

At various points in this review of the literature, I have referred to the lab report as a genre. In this section, I define exactly what I mean by that. Miller (1984) has defined *genre* as "typified rhetorical actions based in recurrent situations" (p. 159). Since then, this particular definition of genre has achieved seminal significance as it has been cited repeatedly in other scholarship. Similarly, Freedman (1995) has defined genres as "conventionally typified responses to situation types, or to situations that are culturally or socially construed as recurrent" and which "reflect both the social dimensions of language use and the socially constructed character of human experience" (pp. 123-124). Simply put, genre is a *social action*. Freedman (1995) has also claimed that since genre is a social action, so too must be writing since forms of writing have been called genres as well (p. 123). Similarly, Russell (2010) has explained that "a genre is the ongoing use of certain material tools (marks, in the case of written genres) in certain ways that people recognize as having worked once and might work again, a typified, tool-mediated response to conditions recognized by participants to be recurring" (p. 357).

What genre is not as Bazerman (1997) and Devitt (1993) have stipulated is a preoccupation with form, text type, vocabulary, organization, and style. Bazerman (1997) has argued that in the classroom, presenting genre as more than form is critical:

> Genres are not just forms. Genres are forms of life, ways of being. They are frames for social action. They are environments for learning. They are locations within which meaning is constructed. Genres shape the thoughts we form and the communications by which we interact. Genres are the familiar places we go to

> create intelligible communicative action with each other and the guideposts we use to explore the unfamiliar. (p. 19)

Hence, while we may be able to identify genre by its evident features, what actually matters more is the rhetorical actions since it is our purpose and context that determine what forms and conventions we use in our communication. In this way, Devitt (1993) has found that "based on our identification of genre, we make assumptions not only about the form but also about the text's purposes, its subject matter, its writer, and its expected reader" (p. 575).

With respect to our discussion of the lab report, though, the concept of genre has raised disagreement and tension. In previous sections of my review of the literature, I evinced that Berkenkotter and Huckin (1993) consider the writing that undergraduate students do to be pedagogical or school-based genres since they serve different purposes, such as teaching and learning, relative to the professional writing of the discipline, which is focused on building and constructing knowledge (pp. 487-488). This appears to be why Lerner (2007) and Russell (2002) have been critical of lab report writing in schools. Russell (1997) has elaborated on what he calls *classroom genres of formal education* by explaining that these are genres derived from the disciplinary activity of experts that are modified and adopted in a way that makes them suitable for the classroom setting (p. 537). Such interpretations emphasize the location, context, and people that use the genre; so the school, classroom, teacher, and student are focused on in this respect.

On the other side of the ledger, Carter et al. (2007) have adamantly maintained that the lab report is an apprenticeship genre since it is specifically designed to prepare

and train students for activity in the science discipline. Thaiss and Zawacki (2006) have gone even further by suggesting that genres in the classroom are nevertheless still genres of the discipline, and therefore should be appreciated as part of the activity of the disciplines. In both cases, the definition of genre as a social action that is typified in recurring situations still remains true. What becomes incongruous is the purpose and context of the lab report. Is it, as Berkenkotter and Huckin (1993) describe, solely a tool for teaching and learning? Or, is it, as Carter et al. (2007) assert, the means that train students for work in the discipline? Answering these questions, of course, isn't particularly easy when relatively little research has been done in this area. By reaching out directly to the teachers and students who teach and learn the lab report, I endeavor to shed light on this issue.

Zone of proximal development (ZPD).

ZPD differs markedly from genre theory since it is often associated with the discipline of education. However, I utilize it in this thesis because it may provide deep insight into the social action between students and teachers in the school setting. Vygotsky (1978) has defined the ZPD as "*the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers*" (p. 86). When Vygotsky (1978) first presented this theory, it was almost unprecedented, because until that point, research in learning and development had focused primarily on the *actual developmental level* (p. 85). The actual developmental level is defined as "the level of development of a child's mental functions

that has been established as a result of already *completed* developmental cycles" (Vygotsky, 1978, p. 85). In other words, mental development was measured by assessing what children could do on their own, such as what tasks or problems they could accomplish independently in the present (Vygotsky, 1978, p. 85). Vygotsky (1978) challenged that notion by asserting that children of the same biological age could achieve varying levels of learning and development given the assistance of an expert, such as a teacher, or a more capable peer (p. 86). In this respect, development was no longer a matter of what had already matured in the child, but rather the potential development that could be achieved given assistance from an expert.

Succinctly, "the actual developmental level characterizes mental development retrospectively, while the zone of proximal development characterizes mental development prospectively" (Vygotsky, 1978, pp. 86-87). Using this prospective perspective, Vygotsky (1978) further claimed that "what is in the zone of proximal development today will be the actual developmental level tomorrow—that is, what a child can do with *assistance* [emphasis added] today she will be able to do by herself tomorrow" (p. 87). Examples of assistance include doing a demonstration, initiating the solution, or asking leading questions (Vygotsky, 1978, p. 86). Cast another way, Vygotsky (1978) has explained that the ZPD triggers learning, which "awakens a variety of internal developmental processes that are able to operate only when the child is interacting with people in his environment and in cooperation with his peers" (p. 90).

Doolittle (1997) has articulated Vygotsky's process of *internalization* in the following way: "A student first experiences an idea, behavior, or attitude in a *social*

setting [emphasis added] and then internalizes this experience so that it becomes a part of the student's mental functioning" (p. 84). Similarly, Eun (2010) has suggested that through collaborative instruction, which assumes a process of internalization, "the strategies of problem-solving that were shared in the intermental plane shift to the intramental plane and the student is able to do on his/her own what was only possible with the assistance and support of more capable others" (p. 408). Therefore, by cognitively internalizing the social experience, the student establishes a foundation on which to independently solve a problem or perform a task in the future. What the ZPD appears to assume is that learning and development is an iterative process with the attainment of new skills via the assistance of an expert as its central goal. Vygotsky (1978) astutely indicated that because the learning process precedes the developmental process, a sequence of ZPDs is engendered within an individual (p. 90). In other words, as students learn skills in a particular subject area, they subsequently form new ZPDs that address skills they haven't obtained independently yet, but will, with the assistance of a teacher. Essentially, one ZPD gives rise to another ZPD, and the learning and development become perpetual.

The method by which development of a student's ZPD takes place in the school setting has occasionally been referred to as scaffolding. In previous sections, I described scaffolding as the process of teachers providing significant assistance to students at the beginning of the course and then gradually tapering it off over time (e.g., Brillhart & Debs, 1981). I expand on that definition by stipulating its relationship with the ZPD. Doolittle (1997) has said that "scaffolding is a three-component process that consists of

(a) presenting a task for student completion that lies at the upper end of the student's zone of proximal development, (b) providing students with the assistance necessary to be successful, and (c) withdrawing the assistance as the student develops in the completion of the task" (p. 97). In this way, scaffolding is seen as three major phases in which students are assigned a task, given measured help by more knowledgeable others, and become gradually independent in completing the task. As a social activity, scaffolding directs and shapes the teaching and learning process in the classroom by informing teachers that they are responsible for providing students the assistance necessary to be successful.

My choice of including Vygotsky's ZPD in this thesis represents my goal of addressing the role of instructors in the teaching and learning of the lab report. The ZPD stresses that it is through the guidance of the teacher, or a more capable and knowledgeable peer, that students are able to mentally develop. Since lab report writing is taught and assigned by teachers to students, I find that the ZPD theory fits the context of my study. In this way, instructors may reveal their attitudes, beliefs, and values when they inform me of their various teaching practices and strategies. At the same time, I hope to cross-check what teachers have told me about their teaching practices and strategies with students. Applying the ZPD to an examination of lab report writing constitutes a new and ambitious approach. Until now, none of the existing literature has considered ZPD theory with regard to lab report writing.

Hypotheses

According to the theories I have described, I have formulated the following hypotheses:

Genre Theory

H_1: Instructors and students believe that the lab report is a pedagogical genre designed for teaching and learning purposes.

H_2: Instructors and students believe that the lab report is an apprenticeship genre designed to prepare and train students for work in the discipline.

ZPD

H_3: Instructors teach the lab report by providing various forms of assistance.

The aforementioned hypotheses constitute my predictions of the attitudes, beliefs, and values of the instructors and students involved with lab report writing. This list of hypotheses, of course, is not exhaustive. It primarily represents the various perspectives suggested in my review of the literature and by my own experiences. In Table 1.1, I stipulate codes, or key words or phrases, which were intimated by my literature review and experiences.

Table 1.1

Hypotheses Codes for Theories

Theory	Hypotheses Codes
▪ Genre	▪ Pedagogical o Teaching o Learning o Homework o Busywork o Following directions o Grading ▪ Apprenticeship o Real or authentic work o Preparation for job o Scientific community o Thinking like a scientist
▪ ZPD	▪ Assistance from teacher ▪ Asking "leading" questions ▪ Learning from mistakes ▪ Teacher as expert ▪ Peer collaboration

Note. Based on my review of the literature and my own experiences taking science lab courses in college.

My thesis expands on the existing literature by applying multiple perspectives in a single study. By considering these a priori propositions, I can anticipate responses from subjects in my own study. In the following chapter, I delineate the methods that I designed in order to test these hypotheses.

CHAPTER 2: METHODS

In this chapter, I describe my experimental design by stipulating the data collection methods, data sources, and data analysis methods. Additionally, I elaborate on the procedures of this study by connecting them to the research questions I established earlier. In the sections that follow, I indicate the major steps I took from creating the research instruments to making meaning out of the data.

Design of Instrumentation

In order to determine the instrumentation I utilize, I first considered my research questions:

(1) *What are the attitudes, beliefs, and values of instructors regarding lab report writing? Why is that the case?*

(2) *What are the attitudes, beliefs, and values of students regarding lab report writing? Why is that the case?*

Since my questions focus specifically on obtaining the attitudes, beliefs, and values of two distinct but related populations, I had to consider methods of data collection that would lead to the discovery of those attitudes, beliefs, and values. In other words, my research questions guided my choice of methods. Because I focused primarily on obtaining qualitative data, I determined that surveys and interviews were the most appropriate means to answer my research questions. By utilizing two different methods,

I implement what Denzin (1978) has called, *methodological triangulation*, which is the use of more than one method when conducting a research study. Specifically, I have adopted *between-method triangulation*, in which I combine dissimilar methods to measure the same units (Denzin, 1978, p. 302), which in my study are the attitudes, beliefs, and values of students and instructors. Denzin (1978) has explained that "the rationale for this strategy is that the flaws of one method are often the strengths of another" (p. 302).

Data collection was conducted in two parts: surveys and interviews. Both data collection methods were conducted concurrently. In my study, the surveys served as a gateway to quickly identify *what* the attitudes, beliefs, and values of instructors and students were. Interviews were intended to elaborate on survey results by asking instructors and students to elaborate on *why* they held those attitudes, beliefs, and values. From Denzin's (1978) perspective, I utilize interviews in order to make up for the weakness of the surveys. In this way, interviews clarified and expounded on results from the survey by asking questions that related to how and why participants held the perceptions that they did. Further, the survey results allowed me to anticipate responses given during interviews. Both methods were consistent in that they asked questions that were aimed at answering the research questions. In the following sub-sections, I elaborate on my strategy for devising the instrumentation of the surveys and interviews. I begin first with the surveys and conclude with the interviews.

Survey instrument design.

One of the primary advantages of surveys is that it facilitates the participation of a large number of people from a population of interest (Singleton, Jr., B. Straits, & M. Straits, 1993, p. 246). For my study, the population of interest would be the biology majors and lab instructors in the Department of Biology at George Mason University. While surveys provide both quantitative and qualitative data, they have limited applicability in explaining why participants hold the perceptions they do. Essentially, the surveys serve as a way to obtain a headcount of how students and instructors felt given a prescribed list of questions. Given that I was investigating two different populations, I developed two different surveys: one for students and one for instructors.

The first step I took in developing my surveys was determining what questions I was going to ask. I let two factors guide me in this regard: my research questions and the theories. Since I was interested in ascertaining the attitudes, beliefs, and values of students and instructors, I decided to be as direct as possible in my questioning. Singleton, Jr., B. Straits, and M. Straits (1993) have defined a *direct question* as "one in which there is a direct, clear relationship between the question that is asked and what the researcher wants to know" (p. 286). A direct question would therefore prompt participants to think about their own experiences. After determining that I would use direct questioning, I integrated my theoretical perspective to circumscribe the focus of my questions. In the previous chapter, I had described genre theory and Vygotsky's ZPD as the theoretical lenses through which I would interpret my study. These theories are

certainly represented in the surveys since the major sections of questions are influenced by at least one of the theories.

On the students' and instructors' surveys, the section called, *The Laboratory Report Itself,* is based on genre theory since the questions refer to the results of socially repetitive actions. The instructor survey contains an additional section called, *Evaluation*, which serves a dual purpose in assessing the pedagogical value of the lab report from the perspective of genre theory and ZPD. Vygotsky's ZPD is represented on the students' and instructors' surveys under the section called, *Instruction*, since the questions focus on how instructors teach the lab report and how students learn it. These sections are clearly demarcated and indicate to participants a shift in focus and theme. With respect to theoretical triangulation, each section of questions aims to answer each of the research questions by highlighting similarities and differences among responses based on the two theoretical perspectives.

Once I established a dual focus of genre and ZPD, I used the literature review and my own experiences as a biochemistry and biology major to develop answer choices for the questions I prescribed. As I assigned answer choices to each question, I realized that not all types of questions were the same. Given this circumstance, I relied on response formats to determine how I wanted to collect the data. Singleton, Jr. et al. (1993) have identified two major types of questions: *open-ended* and *closed-ended* (p. 283). They have defined open-ended as free response questions that require participants "to answer in their own words" (Singleton, Jr. et al., 1993, p. 283). Conversely, closed-ended are fixed-choice questions that require participants "to choose a response from those

provided" (Singleton, Jr. et al., 1993, p. 283). The following types of question formats were included: (a) multiple-choice allowing only one answer, (b) checkbox allowing more than one answer, (c) rating scale, and (d) comment or essay box. A combination of open-ended and closed-ended questions was therefore used. So, for example, closed-ended questions, such as the Likert rating scales were used to ascertain the degree to which participants agreed or disagreed with a statement.

After establishing the questions, organizing them by theme, and determining applicable answer choices, I considered the overall number of questions. In this regard, I took into account how able and willing students and instructors would be to complete the surveys. Given how busy academic life can be, I decided to limit the total number of questions to 16 for students and 15 for instructors, so that a completion time of five to ten minutes would be attainable. This led to the elimination of questions I deemed redundant or unnecessary. Next, I considered the order and flow of questions. I concluded that I should place simpler or easier questions near the beginning of the survey in order to encourage participants to complete the survey. The question difficulty would gradually rise as participants moved from the beginning to the end of the survey. By making the first questions relatively easy to answer, students and instructors would be prevented from "becoming discouraged or feeling inadequate" in fulfilling their roles as participants of the study (Singleton, Jr. et al., 1993, p. 293). Since genre questions ask about social actions that were supposedly already routine to participants, I asked those first. Genre questions were followed by questions influenced by Vygotsky's ZPD. Unlike genre questions, ZPD questions asked participants to recall specific experiences that gave

meaning to their teaching or learning experiences. ZPD questions, therefore, may have required more time to complete than genre questions. In this way, I transition the participants from general topics to specific topics and therefore establish how subsequent topics "flow naturally from the early ones" (Singleton, Jr. et al., 1993, p. 294).

In the final step, I enlisted the service of the online survey developer, *SurveyMonkey*, in order to communicate my surveys in an electronic format. I transcribed each of the questions and applicable answer choices from the word processing document where they were originally created to the electronic survey format. Two surveys were ultimately constructed: one for biology majors and one for lab instructors. Next, I expound on how the second part of the methods were developed: the interviews.

Interview protocol design.

Interviews serve as the means to clarify and give substantive meaning to survey results. To accomplish this, a few steps had to be taken during its developmental phase. First, interview questions had to be about the same topics as survey questions. Doing so would facilitate data crosschecking between surveys and interviews. Second, interviews had to be both structured and flexible enough to introduce additional questioning that could clarify unclear responses. I utilized *semi-structured interviews* to carry this out. Guthrie (2010) has described semi-structured interviews as interviews with pre-established questions that the interviewer is allowed to deviate from by asking intervening questions, such as "open-ended probe questions ('why?')," which were not already stipulated in the protocol (p. 120). In this way, the interviewer is allowed a certain degree of freedom to ask questions that may be pertinent, but are not already

stipulated in writing beforehand. At the same time, the focus of the interview would remain preserved since a pre-established set of questions would prevent the interview from introducing topics that are not germane.

For the interviews, two different protocols were developed: one for students and one for instructors. The protocols serve an important role since they list the instructions that had to be directed to participants, as well as the questions to be asked. Unlike the surveys, all the questions asked in the interview were open-ended, meaning that participants were required to answer in their own words. Like the survey, though, all questions were direct, and were aimed at ascertaining how the participant felt or thought about a topic. Additionally, the sections on which the interviews are constructed are exactly the same as they are for the surveys, as are the theoretical perspectives that guide the formation of each section as well.

The organization and order of questions in the interviews is identical to that of the surveys. Questions are arranged into sections that closely match the theoretical perspective from which they were derived. The sections are then sequenced in order of increasing difficulty with easier sections preceding more difficult sections. Like the surveys, I determined that easier sections would contain more open-ended and general questions, while difficult sections would contain specific and memory-based questions. The primary difference between the surveys and the interviews is the degree of detail asked of participants. This becomes quite apparent simply by taking note of the number of questions asked on the interviews: 23 for students and 17 for instructors. An additional seven questions are asked to students and two more asked of instructors. Since

the interviews were designed to be semi-structured, I invariably asked additional questions apart from the pre-established protocol questions. In this way, I clarified and expounded on the results from the survey by asking participants why they felt and thought the way they did.

In the following section, I discuss the field administration phase of this thesis in which I established contact with members of the community I endeavored to study.

Field Administration

Singleton, Jr. et al. (1993) have defined *fieldwork* as the sequence of actions taken by researchers to apply their methods of data collection to their specific setting of interest. Such actions are manifold and require researchers to consider the nature of the community upon which they are investigating. For this thesis, I have chosen to ascertain the attitudes, beliefs, and values of biology majors and lab instructors in the Department of Biology at George Mason University. Since I conducted my research with students and instructors at the university, I was required to submit any instrumentation or recruitment material to the university's Human Subjects Review Board (HSRB). I sent the following documents to the HSRB for approval:

- survey consent form for students (see Appendix D),
- survey consent form for instructors (see Appendix E),
- interview consent form for students (see Appendix F),
- interview consent form for instructors (see Appendix G),
- survey instrument for students (see Appendix H),
- survey instrument for instructors (see Appendix I),

- interview protocol for students (see Appendix J),
- interview protocol for instructors (see Appendix K),
- survey recruitment e-mail for students (see Appendix L),
- survey recruitment e-mail for instructors (see Appendix M),
- interview recruitment e-mail for students (see Appendix N), and
- interview recruitment e-mail for instructors (see Appendix O).

Once the instrumentation and recruitment material for my study was approved by the HSRB, I moved into the next phase of my fieldwork: gaining community access.

Gaining community access.

Singleton, Jr. et al. (1993) have suggested that a prerequisite step in recruiting participants for a study is "gaining 'official' permission or endorsement" from leaders of the community of which the study focuses on (p. 270). For my study, I identified the community of interest as the Department of Biology at George Mason University. Taking the recommendation of Singleton, Jr. et al. (1993) into account, I initially made contact with the director of the university's undergraduate biology program, Dr. Larry L. Rockwood. In my first meeting with Dr. Rockwood, I explained the purpose and importance of my project, as well as logistical details that required his assistance and approval. Upon the meeting's conclusion, Dr. Rockwood gave his permission for me to conduct my study in the biology department, and provided suggestions on whom to contact in the department as participants. Additionally, Dr. Rockwood invited me to participate in the department's Smithsonian Conservation Biology Institute (SCBI) retreat on writing, which I accepted. This recommendation was markedly important since it

established an opportunity for me to introduce myself to instructors and graduate teaching assistants (GTAs) in the biology department. The SCBI retreat took place on Tuesday, January 15, 2013 in Front Royal, VA, and lasted from mid-morning to late afternoon.

During this time, I met and spoke with several professors and GTAs and participated in the writing workshop in which lab reports were reviewed based on a departmental rubric. Before the workshop, Dr. Rockwood allowed me to give an oral presentation describing my project to the professors and GTAs in attendance. It was also at that time that I answered questions about my project from professors and GTAs and distributed hard copies of the instructor survey to the professors and GTAs present. This was done based on the timing and convenience of having a large number of instructors present. At the same time, though, I had requested Dr. Rockwood to distribute the online version of the survey to lab instructors and GTAs via e-mail, which he had already done before the retreat. Instructors and GTAs were therefore not limited in their options for doing the survey, having the choice of doing it either at the workshop or online.

Following the SCBI retreat, I contacted Dr. Rockwood so that he could assist me with the distribution of e-mails for student recruitment regarding surveys and interviews. Per my request, both recruitment messages were e-mailed out on the biology majors listserv, allowing interested students to complete the survey at their convenience online, and to contact me if interested in participating in a face-to-face interview. Data collection for surveys and interviews concurrently took place between January and March 2013 and lasted approximately eight weeks. In the following section, I stipulate details

on how surveys and interviews were conducted and why I chose to do them the way I did. I begin first with the surveys.

Surveying.

It was important to have surveys distributed via e-mail since it provided the most efficient means to complete the survey. With the exception of the hard copies filled out during the SCBI retreat, I did not believe that distributing hard copies to students was a viable option given the large number of biology majors. Doing so would have required significant organization and manpower, which I could not fulfill alone. Therefore, I determined that doing the surveys electronically was the quickest and most amenable means to collect data from populations of varying sizes. Given that my recruitment e-mail was sent out on the biology majors listserv, this afforded me the greatest chance of reaching the approximately 1,200 biology majors attending the university (George Mason University, 2013). Additionally, having the surveys sent by e-mail eliminated some of the time constraints by allowing students and instructors the flexibility to complete the survey at their convenience.

I designed the process of recruitment to completion to be as simple and user-friendly as possible. In the body of the e-mail, I emboldened and set apart the link to the survey so that it was clearly discernable for readers. Once participants clicked the survey link, they were immediately taken to the informed consent page at which point they were presented with information pertinent to the study. To proceed with the survey, participants had to answer with *Agree* on the informed consent page. The following pages contained the survey questions, which were organized by section. A status

completion bar was located below the questions on each page to estimate how close participants were to completing the survey. Participants were not compelled to answer any question and could exit the survey at any time. I indicated an estimated completion time of five to ten minutes, but participants were allowed as much time as they needed. Although I only intended for biology majors to take the student survey, students from other majors took it as well. The results of students from other majors were filtered out since the focus of this study is on biology majors only.

Next, I discuss how I conducted the interviewing phase of my study, which required much more organization and time to complete.

Interviewing.

By conducting interviews, I aimed to clarify and deepen the survey results in this study. Each of the interviews was conducted one-to-one, involving only myself as interviewer and the participant as the interviewee. To recruit student participants, I utilized the same strategy as the surveys by having my recruitment e-mail distributed on the biology majors listserv. With respect to instructors, I contacted five professors and four GTAs, many of whom I had met at the SCBI retreat and whom Dr. Rockwood suggested would be helpful. Of the nine, I was able to interview three of the five professors and all four GTAs.

Conversely, determining the students to interview was not as simple a task compared to instructors. In my recruitment e-mail for students, I offered a $15 cash payment as incentive and compensation for participating. Upon having my recruitment e-mail distributed on the biology majors listserv, I received e-mails from 94 students

expressing interest in participating. I surmised that at least some of the student interest was due to the money involved. However, because I intended to interview a maximum of 20 students, I constructed a list of 20 prospective students by randomly selecting from the 94 e-mails of students who responded. Upon realizing that not all of the 20 students I initially selected would participate, I constructed a second list of 20 prospective students. Difficulties during the interview process included students not responding to follow up e-mails or not showing up to the interview. Overall, I contacted 40 students of which 19 participated. In this way, I conducted what Singleton, Jr. et al. (1993) have referred to as *convenience sampling* since I selected a requisite number of participants from a list of those who identified themselves as interested in participating (pp. 159-160). Before the scheduled date of the interview, I e-mailed a copy of the informed consent form to prospective participants for their perusal.

As I scheduled interview dates, I also considered the setting in which interviews would take place. All of the professors I interviewed had agreed to have their interviews conducted in their offices. Interviews for students and GTAs were conducted in study rooms I reserved at Fenwick Library. The office setting and study room setting were amenable to the conditions I wanted: A quiet and undisturbed setting where the participant could focus on the questions at hand, and in which audio recording could take place without interference from external noise. While meeting with professors was merely a matter of finding their office, meeting with students and GTAs required more flexibility and planning.

When I initially met with students and GTAs, I waited in the front lobby of the library. Prior e-mails establishing interview dates and times instructed students and GTAs that I would greet them at the front lobby and accompany them to the study room. As I walked each student or GTA to the study room, I would introduce myself and ask whether he or she had any questions that I could answer. After settling into the study room, I once again gave each student or GTA an opportunity to ask any questions before I began the interview. From this point on, interview procedures were conducted identically among instructors and students. All interviews were conducted *face-to-face*, or in person, and produced significantly detailed and substantive responses. Singleton, Jr. et al. (1993) have found that the *response rate*, which is the proportion of people who complete the interviews or surveys, is generally higher for face-to-face interviewing since the interviewer's presence lends credibility to his or her study (p. 261). This certainly turned out to be true for my study since all interview participants attempted to answer each one of the questions I asked.

Before beginning the interview, I allowed instructors and students to fill out and submit their informed consent forms. I indicated I would start the interview when I powered on the digital audio recorder. When I conducted the interviews, I adopted the procedural guidelines for interviewing outlined by Singleton, Jr. et al. (1993). In each interview, I did the following: (a) initiated the interview, (b) put the participant at ease, (c) was businesslike, (d) kept the interview situation as private as possible, (e) avoided stereotyping, (f) was thoroughly familiar with the protocol, (g) asked every question in its proper sequence and exactly as written, (h) did not assume the answer to any question, (i)

spoke slowly in a clearly understood and well-modulated voice, (j) did not put answers in the participant's mouth, (k) used an appropriate, neutral probe when needed, and (l) recorded responses on the interview protocol as I went along (Singleton, Jr. et al., 1993, pp. 274-275).

At the beginning of the protocol, I assigned numerically based pseudonyms to all participants in order to protect their privacy. So, for example, students were identified as Student #1, Student, #2, Student #3, etc., while professors and GTAs were identified as Instructor #1, Instructor #2, Instructor #3, etc. After I read through each question, I carefully listened to each participant's answer and took notes on my protocol by writing down unusual, interesting, or striking answers. These notes were invaluable since they were the basis of most of the intervening questions that I asked that were not part of the original protocol. Occasionally, participants had questions about my questions to which I would clarify and explain what I was asking. Although I estimated that interviews would take between 30 to 45 minutes for students, and 30 minutes for instructors, durations often varied. The time to conduct student interviews ranged from approximately 20 minutes to an hour, while the time to conduct instructor interviews ranged from approximately 25 to 50 minutes. At the conclusion of each interview with students, I compensated each student with $15 as stipulated on the informed consent form. Of the 19 student participants, 17 accepted the cash payment, which produced a total expenditure of $255.

In the following section, I describe my process for conducting the analysis of data for the surveys and the interviews.

Data Analysis

Grant-Davie (1992) has defined data as "any raw material or information gathered or observed in the course of a research project and considered relevant to the research" (p. 271). The data from my project would be the responses given on the surveys and interviews that I conducted. For each data collection method that I used, I chose data analysis methods that would parse the data most effectively and fittingly. In other words, the data collection method determined the data analysis method. For surveys, I analyzed the results by conducting univariate analysis and coding. For interviews, I relied exclusively on coding.

Univariate analysis.

Singleton, Jr. et al. (1993) have referred to univariate analysis as "techniques for examining one variable at a time" (p. 426). This is done by forming a *frequency distribution* "by first listing all the response categories and then adding up the number of cases that fall into each category" (Singleton, Jr. et al., 1993, p. 427). Next, *percentage distributions* are calculated to "provide an explicit comparative framework for interpreting distributions" (Singleton, Jr. et al., 1993, p. 428). When examining data from surveys, these were essential elements to report. Since I conducted the survey through the online services of SurveyMonkey, I was afforded certain perks that assisted my examination of the data. For example, a results page allowed me to view the total counts and percentages assigned to each response category for each question, or in other words, the frequency distributions and percentage distributions described by Singleton, Jr. et al.

(1993). At that point, it became a matter of determining how to represent that data in my study.

I concluded that each question type would influence how I reported the data. Multiple choice checkbox questions in which more than one answer was allowed was reported in tabular form and organized to highlight a descending order of response counts and percentages. Response categories for these questions were simply taken from the question and rearranged to indicate higher rated responses near the top of each table. Not all question responses were represented in tabular form though. For questions that used a response scale, such as Likert scaling, data was conveyed graphically in diverging bar charts, either stacked or individual. I chose to show the data this way since it provides an efficient and straightforward visualization of the number and proportion of attitudes regarding particular statements. The colors and spatial arrangement of the bars emphasize how strongly participants disagree, agree, or are neutral to particular statements. In the next section, I describe my methodology for coding.

Coding.

Coding was central to my data analysis of the interviews. Before beginning the actual process of coding, though, I first had to transcribe audio recordings of the interviews into written form. To do this, I transferred all the audio files to my laptop, and subsequently transcribed each audio file as I listened to each interview. I utilized a transcription foot pedal and transcription software in order to facilitate this process. By using the transcription foot pedal, I could easily fast-forward, rewind, or play the audio recording by applying pressure to designated parts of the pedal. Additionally, I used

Express Scribe, an audio player software that corresponds to the transcription foot pedal. This approach allowed me to streamline the transcription process by collating all the audio files into a program that allotted space for typing text and for controlling audio speed. Following transcription, I re-transcribed each interview from the text space in Express Scribe to a word-processing document. I produced a total of 26 word-processing documents, and named each of the documents according to the pseudonym I assigned each participant at the time of the interview. I decided to transfer the text to word-processing documents since I believed that the word-processing comment features would facilitate coding. Once word-processing documents were appropriately named and all text was fully re-transcribed, I deemed the text ready for coding.

Grant-Davie (1992) has described coding as "the process of identifying units of analysis and classifying each unit according to the categories in a coding system—either a preexisting system or one developed for the data in question" (p. 272). Similarly, Saldaña (2013) has defined a *code* as "a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data" (p. 3). I synthesize Grant-Davie's (1992) and Saldaña's (2013) definitions by assigning words or short phrases derived from the hypotheses I proposed in the previous chapter (see Table 1.1), and by assigning words or short phrases based on emergent themes that were heretofore unanticipated. Therefore, it appears that Grant-Davie (1992) suggested two types of coding strategies: *deductive* and *inductive*. Deductive coding refers to using a pre-established set of codes to interpret the data under examination (Fereday & Muir-Cochrane, 2006, p. 91; Thomas, 2006, p. 238). Inductive

coding refers to deriving codes by considering emergent themes within the data under examination (Fereday & Muir-Cochrane, 2006, p. 91; Thomas, 2006, p. 238). I therefore utilized a combination of deductive and inductive coding.

As I read through each interview, I utilized the comment feature in the word-processing document to mark a code. Students and instructors were analyzed separately with each group having its own set of codes. I highlighted words, phrases, and extended portions of text to correspond with the codes that I determined. While some of the codes were anticipated based on the hypotheses codes, most were new and therefore suggested themes that up to this point have gone unrealized. In order to keep my focus on answering my research questions, I adopted two more coding strategies: *values coding* and *descriptive coding*. Saldaña (2013) has stipulated that values coding "is the application of codes onto qualitative data that reflect a participant's values, attitudes, and beliefs, representing his or her perspectives or worldview" (p. 110). Descriptive coding refers to "the basic topic of a passage of qualitative data" (Saldaña, 2013, p. 88). These coding strategies determined the focus of my coding.

As I coded, I assigned one of four letters to characterize my codes: *A* for attitude, *B* for belief, *V* for values, and *D* for Description. While attitudes, beliefs, and values are similar, they are not the same. I distinguished among them by adopting Saldaña's (2013) perspective. Saldaña (2013) has defined a *value* as "the importance we attribute to oneself, another person, thing, or idea;" an *attitude* as "the way we think and feel about ourselves, another person, thing, or idea;" and a *belief* as "personal knowledge, experiences, opinions, prejudices, morals, and other interpretive perceptions of the social

world" (p. 111). I primarily used descriptive coding to keep track of the topics that I encountered. Saldaña (2013) has categorized values and descriptive coding as *first cycle coding methods* since they are "processes that happen during the initial coding of data" (p. 58).

Once I completed first cycle coding, I moved into *second cycle coding methods*. Saldaña (2013) has asserted that "the primary goal during Second Cycle coding is to develop a sense of categorical, thematic, conceptual, and/or theoretical organization" from the first cycle codes (p. 207). To do second cycle coding, I transcribed all the codes from all 26 word processing documents to a separate word-processing document. In that document, I sorted codes into groups and assigned categorical names. I eliminated codes that were redundant or irrelevant. Once all pertinent codes were categorized, I began to group similar categories together in order to form themes. This strategy required building from the bottom-up by using codes to form categories, and categories to form themes. Such would be an accurate assessment if only referring to an inductive coding strategy. However, because I also created hypotheses codes, my theoretical perspectives influenced some of the codes, categories, and themes. Therefore, deductive coding required building from the top-down by searching the data for pre-determined theoretical perspectives.

After I organized and ordered the codes into categories and themes, I endeavored to find out the frequency distributions of each code by reexamining each of the 26 word documents. Rather than count the number of times a code appeared in the text, I counted the number of participants who brought up each code. Namey et al. (as cited in Saldaña,

2013) have suggested determining frequencies "on the basis of the number of individual participants who mention a particular theme, rather than the total number of times a theme appears in the text" (p. 86). Grant-Davie (1992) has cautioned against counting every instance that a code appears in the text because "verbose subjects will generate many more units of a given kind of comment by repetition than subjects who are more concise" (p. 276). By merely counting the number of times the code appears in the text, the frequency counts may mislead and skew the data interpretation. Therefore, to avoid redundancy, I have counted codes based on the number of participants who raised them during interviews.

Inductive, deductive, values, and descriptive coding strategies were applied to all interview transcripts. Additionally, because a select number of questions on instructor surveys required short answers, coding was applied to that data as well. I utilized the same coding strategies that I used for interviews for these select survey responses.

In the following chapter, I display the results of my study.

CHAPTER 3: RESULTS

This chapter presents the data I obtained from the surveys and interviews I conducted with students and instructors. Survey data is displayed first, and is followed by interview data. I have subdivided each data collection method into *Students* and *Instructors* in order to highlight differences between the two groups. When appropriate, data is organized in descending order to emphasize more frequently found elements first.

Surveys

This section presents data collected through the electronic surveys. Data is presented in the following forms: tables, figures, and block quotes. Coded data from surveys is presented in tables, and is indicated by the stub head, *Code*.

Student responses.

In this section, I display student responses to the student survey.

Table 3.1

Demographics for Student Surveys

Level	Number of Participants	Percentage
▪ Freshman	12	16.4
▪ Sophomore	17	23.3
▪ Junior	17	23.3
▪ Senior	27	37
▪ Total	73	100

Note. Based on student survey, Q2: "What is your undergraduate level?"

Table 3.2

Most Challenging Aspects of Doing a Lab Report

Aspect	Number of Participants	Percentage
▪ Analysis of Data	40	55.6
▪ Calculations	34	47.2
▪ Writing	20	27.8
▪ Organization	15	20.8
▪ None of the above	5	6.9
▪ Other	11	15.3

Note. Based on student survey, Q7: "What are the most challenging aspects of doing a lab report? Check all that apply." Total number of participants to this question: 72. Percentages for each *Aspect* are calculated by dividing the *Number of Participants* by the total number of participants who answered this question, followed by multiplying that value by 100. Therefore, for *Analysis of Data*: (40/72) * 100 = 55.6%. Percentages do not add up to 100 because participants are not limited to choosing one answer.

Table 3.3

Most Important Elements Considered During Evaluation

Element	Number of Participants	Percentage
▪ Discussion of Results	63	87.5
▪ Figures, Tables, Graphs	50	69.4
▪ Organization	35	48.6
▪ Accuracy of Data	34	47.2
▪ Grammar	24	33.3
▪ Formatting	17	23.6
▪ Writing Style	16	22.2
▪ Writing Mechanics	13	18.1
▪ Other	2	2.8

Note. Based on student survey, Q8: "When a lab report is evaluated and graded, what do you think are the most important elements that should be looked at? Check all that apply." Total number of participants to this question: 72. Percentages for each *Element* are calculated by dividing the *Number of Participants* by the total number of participants who answered this question, followed by multiplying that value by 100. Therefore, for *Discussion of Results*: (63/72) * 100 = 87.5%. Percentages do not add up to 100 because participants are not limited to choosing one answer.

Table 3.4

Resources Consulted

Resource	Number of Participants	Percentage
▪ Written comments and feedback on graded lab reports	62	86.1
▪ Advice from other students	45	62.5
▪ Meeting with Instructor/TA during office hours	40	55.6
▪ Online resources	36	50.0
▪ Student writing center	4	5.6
▪ None of the above	4	5.6
▪ Other	2	2.8

Note. Based on student survey, Q13: "Which of the following resources have you ever consulted with when writing lab reports? Check all that apply." Total number of participants to this question: 72. Percentages for each *Resource* are calculated by dividing the *Number of Participants* by the total number of participants who answered this question, followed by multiplying that value by 100. Therefore, for *Written comments and feedback on graded lab reports*: (62/72) * 100 = 86.1%. Percentages do not add up to 100 because participants are not limited to choosing one answer.

The following quotes elaborate on students' rationales for selecting the resources they do. Two of the top three selections from Table 3.4, comments and instructors, are presented here:

Comments

- Written comments because they evaluate our writing and our specific weaknesses/strengths.

- Written comments on graded reports. With the rubrics being so overly-general, graded reports are the only way to know the details of just what the instructor is expecting.

- Written comments and feedback on graded lab reports. The form of writing a lab report is not universal. It is very dynamic, not all instructors want the same format, which can be very difficult sometimes. So therefore, looking back at other lab reports helps to figure out how the instructor wants it.

- Written comments and feedback on graded lab reports helped the most because it allowed for the TA to say what needed to be added or corrected. This made it easier when writing the next report to see what changes needed to be made.

- Written comments. Though it hurts to lose points on a report, it is easier to know what the instructor wants by letting them mark you wrong. There are times when I ask the instructor what they want from my report, but even they do not know what they want or aren't willing to put in the time to clear things up for me.

- Teacher comments. But each teacher has a different style, organizational preference, everything. So in the end, there was no department-wide agreed-upon standard for lab reports.

Instructor/TA

- Every professor has their own style and expectations when it comes to lab reports. What works for one professor may not work for another. It's important to know exactly what each professor wants so the student's grade will not suffer.

- Meeting with my instructors helped me out the most. I could go and ask them specific analysis/ calculation problems I had and double check if I was understanding the material. Getting their affirmation and their comments on my analysis helped me write a better report.

- Meeting with the instructor--- Each instructor is different and requires specific things when it comes to writing lab reports so speaking with the instructor directly is more beneficial.

- Meeting with the TA simply because they know what they are looking for when grading papers. They usually explain things to allow for better understanding of the concepts.

- Meeting with the instructor was often most helpful as every instructor has different lab report requirements and methods of grading.

- Meeting with TA, because they can give you detailed info on what they want and how to do problems, and you know that you're doing what's expected by the person who grades it.

- I think the lab ta [*sic*] was the most helpful. Because each has their own way of grading and that doesn't come from simply following a rubric but from the TA. Although I follow the rubric word for word the professor still finds a way to take off points.

- Getting the TA's preference on the reports is the most useful. The TA is the only one that knows how he/she will grade your paper, all other sources of information are pretty much useless.

Table 3.5

Methods to Improve Teaching

Method	Number of Participants	Percentage
▪ A detailed template of a sample lab report	64	88.9
▪ A list of grading guidelines/rubric	62	86.1
▪ Lesson on lab report writing given by the instructor/TA	39	54.2
▪ A list of possible online resources about lab report writing	30	41.7
▪ Extended office hours of instructor/TA	20	27.8
▪ Other	8	11.1

Note. Based on student survey, Q15: "Which of the following do you think would help your writing of lab reports the most? Check all that apply." Total number of participants to this question: 72. Percentages for each *Method* are calculated by dividing the *Number of Participants* by the total number of participants who answered this question, followed by multiplying that value by 100. Therefore, for *A detailed template of a sample lab report*: (64/72) * 100 = 88.9%. Percentages do not add up to 100 because participants are not limited to choosing one answer.

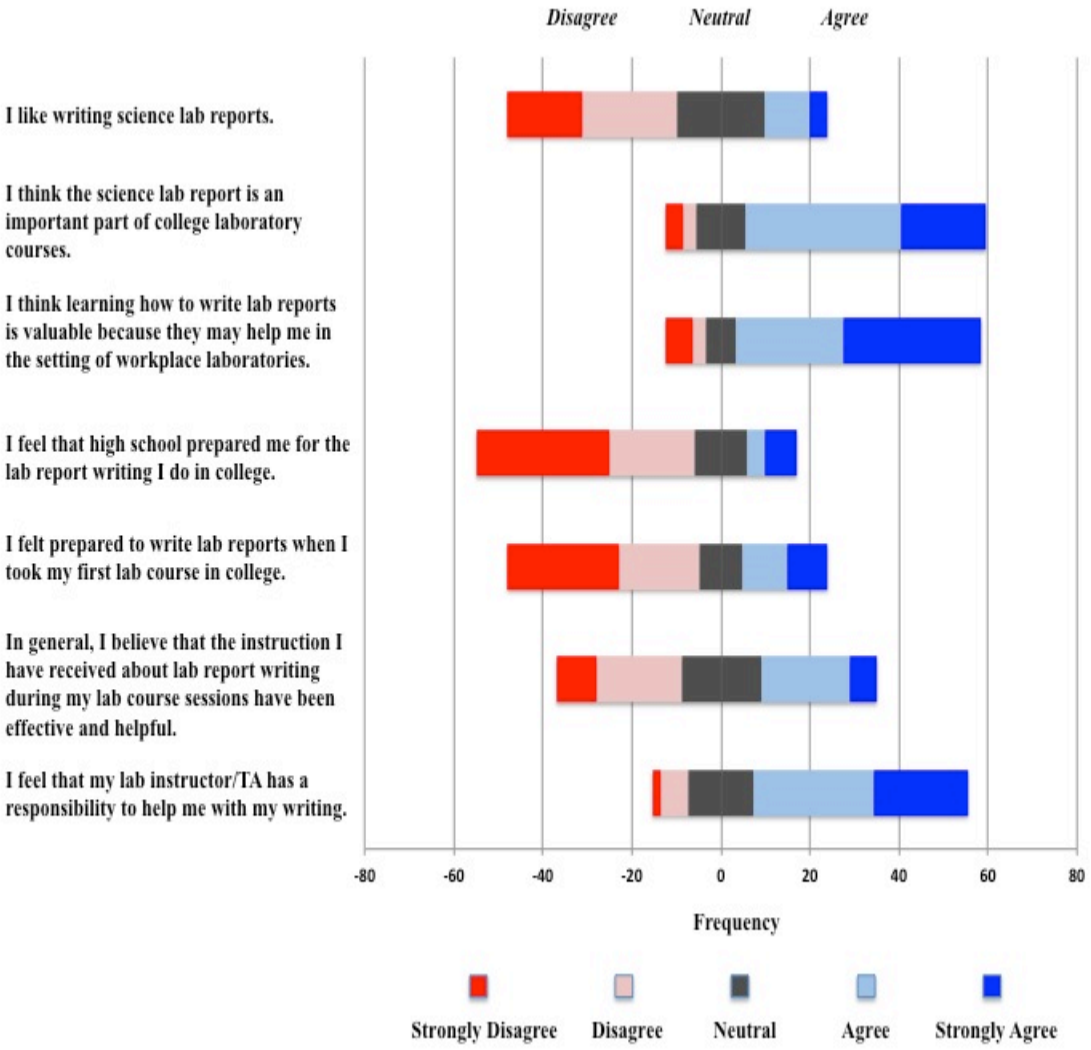

Figure 3.1. Diverging stacked bar chart for statements assessed on a Likert scale based on Q4, Q5, Q6, Q9, Q10, Q11, and Q12 on student survey. Statements for these questions are stipulated on the chart. Indicates the relative proportions to which students agree or disagree with a position statement. The farther to the left a bar stretches, the more students disagree with that statement; the shaded red area indicates this position. The farther to the right a bar stretches, the more students agree with that statement; the shaded blue area indicates this position. Students taking a neutral position are visually represented by the shaded gray area along the 0 on the *Frequency* count of the x-axis. A diverging stacked bar chart allows for relative comparisons between position statements through recognition of color and spatial arrangements.

Instructor responses.

In this section, I display instructor responses to the instructor survey.

Table 3.6

Purpose of Lab Report

Code	Number of Participants
▪ Pedagogical (learning)	9
▪ Apprenticeship (disciplinary)	2

Note. Based on instructor survey, Q5: "What do you think the purpose of the lab report is? If you prefer not to respond, please type 'N/A.'" Since this is an open-ended question, I coded instructor responses to represent the data.

Table 3.7

Important Features of Lab Report

Code	Number of Participants
▪ Structure	5
▪ Data interpretation	4
▪ Integrates literature	4
▪ Comprehension (shows understanding)	4
▪ Grammar	3
▪ Formatting	2
▪ Clarity	2
▪ Mechanics	2
▪ Critical thinking	1
▪ Repeatability	1

Note. Based on instructor survey, Q6: "Please list the features of a satisfactory lab report. If you prefer not to respond, please type 'N/A'" and Q7: "Please list the features of an unsatisfactory lab report. If you prefer not to respond, please type 'N/A'." Since these are open-ended questions, I coded instructor responses to represent the data.

Table 3.8

Rubric for Evaluation and Grading

Rubric	Number of Participants	Percentage
▪ Yes	9	81.8
▪ No	1	9.1
▪ Prefer not to respond	1	9.1

Note. Based on instructor survey, Q8: "Do you use a rubric to evaluate and grade student lab reports?" Total number of participants to this question: 11. Percentages for each choice are calculated by dividing the *Number of Participants* by the total number of participants who answered this question, followed by multiplying that value by 100. Therefore, for *Yes:* (9/11) * 100 = 81.8%. Percentages add up to 100 because participants are limited to choosing one answer.

Table 3.9

Components of Rubrics

Code	Number of Participants
▪ Introduction	4
▪ Methods	4
▪ Results	4
▪ Discussion or Conclusion	4
▪ Literature citations	4
▪ Grammar	3
▪ Organization and structure	2
▪ Abstract	2
▪ Content	2
▪ Style	2
▪ Formatting	2
▪ Math	1

Note. Based on instructor survey, Q9: "Please list the criteria that you use to evaluate student lab reports, and the proportions to which they form the grade. (e.g. Introduction = 10%, Grammar = 5%, Graphs/Tables = 15%, etc.) If you prefer not to respond, please type 'N/A'." Since this is an open-ended question, I coded instructor responses to represent the data.

Table 3.10

Identifying Student Problems

Problems	Number of Participants	Percentage
▪ Discussion of Results	11	100
▪ Grammar	8	72.7
▪ Writing Mechanics	6	54.5
▪ Figures, Tables, Graphs	5	45.5
▪ Organization	4	36.4
▪ Writing Style	4	36.4
▪ Formatting	3	27.3
▪ Accuracy of Data	2	18.2
▪ Other	1	9.1

Note. Based on instructor survey, Q11: "When you evaluate lab reports, where do you notice students struggle the most? Check all that apply." Total number of participants to this question: 11. Percentages for each *Problem* are calculated by dividing the *Number of Participants* by the total number of participants who answered this question, followed by multiplying that value by 100. Therefore, for *Discussion of Results*: (11/11) * 100 = 100%. Percentages do not add up to 100 because participants are not limited to choosing one answer.

Table 3.11

Reasons for Student Difficulties

Code	Number of Participants
▪ Students are inexperienced	7
▪ Students have preconceptions	1

Note. Based on instructor survey, Q13: "Have you found it necessary to give 'lessons' on writing lab reports to your students? If yes, explain why. If no, explain why not. If you prefer not to respond, please type 'N/A'." Since this is an open-ended question, I coded instructor responses to represent the data.

Table 3.12

Advice from Teachers

Code	Number of Participants
▪ Consult with peers	2
▪ Revise and edit	2
▪ Read it out loud to yourself	2
▪ Find relevant literature	1
▪ Metacognition	1
▪ Be specific	1
▪ Be clear	1

Note. Based on instructor survey, Q14: "What are one or two pieces of writing advice, if any, that you find yourself giving most often to students writing science lab reports? If you prefer not to respond, please type 'N/A'." Since this is an open-ended question, I coded instructor responses to represent the data.

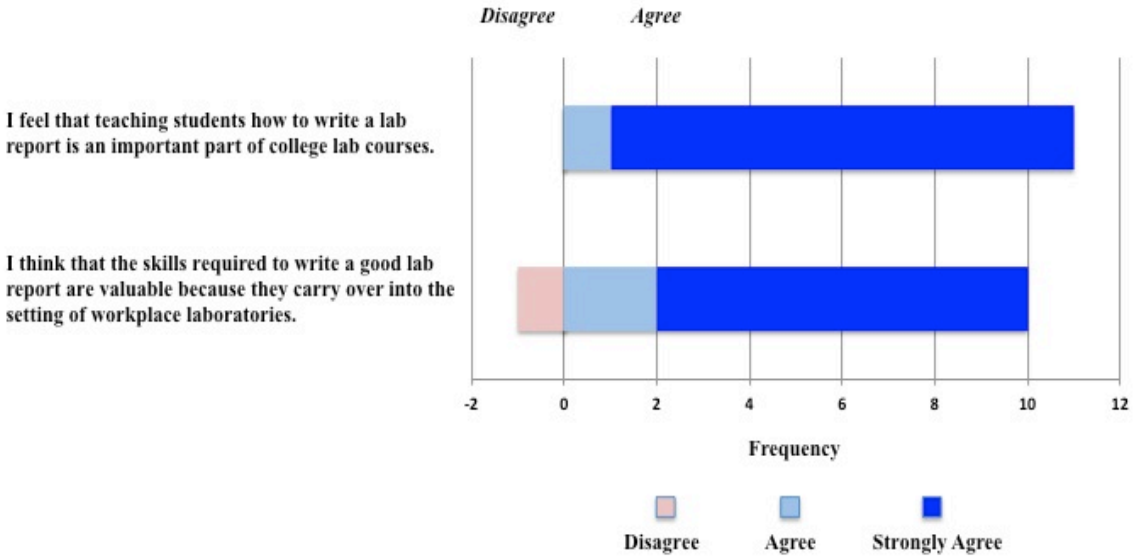

Figure 3.2. Diverging stacked bar chart for statements assessed on a Likert scale based on Q3 and Q4 of instructor survey. Statements for these questions are stipulated on the chart. Indicates the relative proportions to which instructors agree or disagree with a position statement. The farther to the left a bar stretches, the more instructors disagree with that statement; the shaded pink area indicates this position. The farther to the right a bar stretches, the more instructors agree with that statement; the shaded blue area indicates this position. A diverging stacked bar chart allows for relative comparisons between position statements through recognition of color and spatial arrangements.

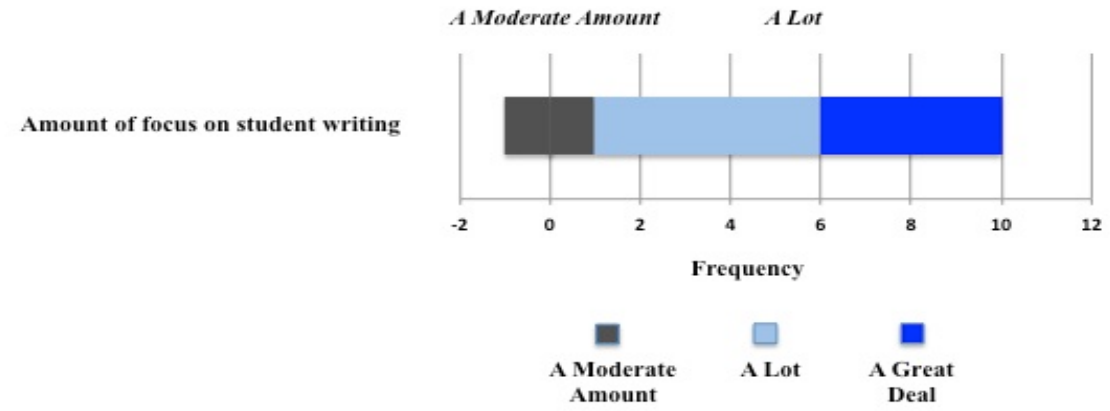

Figure 3.3. Divergent bar chart for statement assessed on a Likert scale based on Q10 of instructor survey. Based on Q10: "How much weight and/or focus do you place on the actual student writing itself?" Indicates the relative proportions to which instructors focus on student writing.

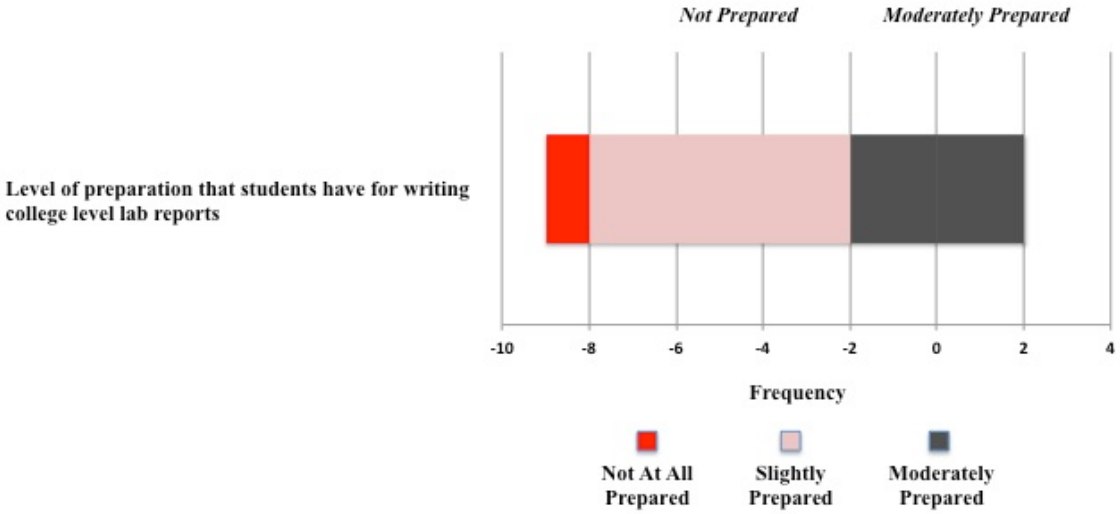

Figure 3.4. Divergent bar chart for statement assessed on a Likert scale based on Q12 of instructor survey. Based on Q12: "How prepared do you think your students are to produce the level of writing required for undergraduate science lab reports?" Indicates the relative proportions to which instructors feel students are prepared for writing lab reports in college.

Interviews

This section presents codes derived from interview data. Codes are arranged by categories, which are themselves then organized by theme. The number of participants from which a code was derived is indicated in each table. Codes were derived through a holistic examination of the data. Although the data displayed in each table does not refer to the answers given exclusively to a single question, I have added notes that indicate the questions on which the codes were primarily derived.

Student codes.

In this section, I present codes derived from the data collected via interviews with students. See Appendix P for an excerpt of coding done on a transcript of a student interview.

Table 3.13

Demographics for Student Interviews

Class Level	Number of Participants
• Freshman	5
• Sophomore	4
• Junior	5
• Senior	5

Note. Based on student interview, demographic question: "What is your undergraduate level (e.g. freshman, sophomore, junior, senior, other)?"

Identifying genre.

In this section, I present categories of codes related to *identifying genre*: pedagogical genre, apprenticeship genre, and writing. These codes represent how students view the lab report as a genre because of its social action.

Table 3.14

Pedagogical Genre

Code	Number of Participants
▪ Finding out teacher expectations o What to include	19
▪ Classroom setting	19
▪ Grading and assessment	19
▪ Teacher as audience	19
▪ Teacher feedback and commentary	16
▪ Getting the correct answer o Searching for "right" or "wrong" answers	13
▪ Turning in assignment	13
▪ Earning points	11
▪ Rubric	9
▪ Following instructions o Completion	8
▪ No plagiarism, cheating, copying	8
▪ Teacher identifies mistakes	8
▪ Due dates	6
▪ Workload of a "science major"	4
▪ Teachers have correct answers	4
▪ Analogous to an exam	3
▪ Reading the course syllabus	2
▪ Getting an A grade	1
▪ "Class requirement"	1
▪ "If you were actually in the field, you would need to do that just for yourself, not really for any other reason." o Solely pedagogical	1

(Table 3.14 continues)

Table 3.14 continued

Code	Number of Participants
▪ Not useful to all science majors	1
o Not every science major goes into the discipline after graduating	
▪ Busywork	1

Note. Based primarily on student interview, Q1: "Tell me about your experiences writing science lab reports."

Table 3.15

Apprenticeship Genre

Code	Number of Participants
▪ Preparation and training	17
o For real and authentic work	
o Enhances ethos	
▪ Transfer	16
o Classroom to discipline	
▪ Disciplinary activity	14
▪ Communicates to other scientists	9
▪ Record-keeping	9
▪ "Real" world/life	9
▪ Written with repeatability in mind	5
▪ Imitation of authenticity	3

Note. Based primarily on student interview, Q7: "How much value do you think the lab report carries in the setting of workplace laboratories?"

Table 3.16

Writing

Code	Number of Participants
▪ Content	17
▪ Clear and concise	16
▪ Specific	15
▪ Format	15
▪ Mechanics	14

(Table 3.16 continues)

Table 3.16 continued

Code	Number of Participants
▪ Grammar	13
▪ Punctuation	11
▪ Writing is discipline specific skill	9
▪ Direct	7
▪ Tense	6
▪ Knowing page number requirements	5
▪ Coherent	5
▪ Writing is generalizable skill	4
▪ Flow	3
▪ Objective tone	2

Note. Based primarily on student interview, Q8: "How do you think the lab report should be formatted and/or structured?" Q9: "What do you think the features of a satisfactory lab report are?" Q10: "What do you think the features of an unsatisfactory lab report are?" and Q19: "What are one or two pieces of writing advice you have heard most frequently regarding science lab report writing?"

How students learn.

In this section, I present categories of codes related to *how students learn*: metacognition, meta-processing, epistemology, pre-college experience, consulting more knowledgeable others, course provided materials, university resources, and online resources. These codes represent the various ways that students think about lab reports, the learning strategies they practice, and the resources available to them.

Table 3.17

Metacognition

Code	Number of Participants
▪ Connecting the "doing" with the "knowing" and the "writing"	15
▪ Clarifies the experiment	15
▪ Connecting lecture and lab	10
▪ Critical analysis, thinking	8
▪ Meaning making	7
▪ Understanding purpose of lab	6
▪ Comprehension	5
▪ "Practical" way to understand concepts	5
▪ Self-assessment	4
▪ Reflection o "Refreshes your mind" o Retrospective learning tool	4
▪ Evaluation	3
▪ Going beyond the "textbook"	3
▪ Making logical connections	2

Note. Based primarily on student interview, Q5: "What are the most challenging aspects of writing a lab report?" Q9: "What do you think the features of a satisfactory lab report are?" and Q10: "What do you think the features of an unsatisfactory lab report are?"

Table 3.18

Meta-Processing

Code	Number of Participants
▪ Teachers read, examine, and grade	19
▪ Determining instructor idiosyncrasies	17
▪ Practice attempts	16
▪ Making changes based on teacher comments	15
▪ Learning from mistakes	15
▪ Iteration	14
▪ Collaboration	11
▪ Time-consuming process	8
▪ Scaffolding	4
▪ Solitary cognitive development	3

Note. Based primarily on student interview, Q3: "Based on your experiences, tell me what you like about writing lab reports;" and Q4: "Based on your experiences, tell me what you don't like about writing lab reports."

Table 3.19

Epistemology

Code	Number of Participants
▪ Demonstrate knowledge	17
▪ Explaining WHY something happened	9
▪ Explaining error	8
▪ Drawing conclusions from data	5
▪ Experiential learning (seeing it, doing it)	5
▪ Focus on data analysis	5
▪ Identifying and answering "research question"	3
▪ Building a strong science vocabulary o Understands terminology	3
▪ Background knowledge	3
▪ Understanding the "big picture"	2
▪ Make sure citations match bibliography	2

Note. Based primarily on student interview, Q5: "What are the most challenging aspects of writing a lab report?" and Q6: "Why do you think the lab report is important in college-level lab courses?"

Table 3.20

Pre-College Experience

Code	Number of Participants
• High school = did NOT prepare	11
• AP Courses	8
• Regular Courses	8
• High school = some preparation	8
• IB Courses	3
• Dual Enrollment	1

Note. Based primarily on student interview, Q11: "How much did high school help to prepare you for the level of lab report writing required in college?" and Q12: "Did you feel prepared to write lab reports when you took your first science lab course?"

Table 3.21

Consulting More Knowledgeable Others

Code	Number of Participants
▪ Student's own instructor	16
▪ Peers	12
▪ "Classmates"	5
▪ "Friends" outside class	3
▪ Other majors in disciplines outside science	3
▪ Affiliate instructor	2
▪ "Lab partner"	2
▪ "Science tutors"	2
▪ Limitations of asking peer on same level: they don't know either	1
▪ Peer help with "Microsoft Excel" o "Someone showed me how to do it"	1
▪ "Roommate" who is also a biology major	1
▪ "Asked my brother" o Assisted with Microsoft Excel	1
▪ "Floor-mates" in residence hall	1

Note. Based primarily on student interview, Q14: "Did you consult any resources in order to write your lab reports?" and Q15: "What resource did you find most helpful when you wrote your lab reports?"

Table 3.22

Course Provided Materials

Code	Number of Participants
▪ "Samples"/"Examples" of lab reports	16
▪ Lab manual	12
▪ "Textbook"	8
▪ Template with descriptions of each section	7
▪ Instructor's "office hours"	5

(Table 3.22 continues)

Table 3.22 continued

Code	Number of Participants
▪ PowerPoint presentation tailored to particular lab	5
▪ "Guides"	4
▪ Notes from lecture	4
▪ "Blackboard" website	3
▪ "Handouts"	3
▪ Syllabus	2
▪ Recommended books from instructor	1

Note. Based primarily on student interview, Q14: "Did you consult any resources in order to write your lab reports?" and Q15: "What resource did you find most helpful when you wrote your lab reports?"

Table 3.23

University Resources

Code	Number of Participants
▪ "Writing center": unhelpful o Designed for English majors o No expertise on scientific writing o Lack of content knowledge	10
▪ "STAR" lab offers classes on "Microsoft Excel"	4
▪ "Writing center" = helpful o Heard from other students that it was "fairly helpful"	1
▪ "Learning assistant program through the STEM Accelerator" o STEM tutors (already went through lab course)	1

Note. Based primarily on student interview, Q14: "Did you consult any resources in order to write your lab reports?" Q15: "What resource did you find most helpful when you wrote your lab reports?" and Q18: "Did your lab instructor/TA ever suggest that you seek outside help (e.g. writing center, how-to guides, websites, etc.)?"

Table 3.24

Online Resources

Code	Number of Participants
▪ "E-mail" (to the instructor)	17
▪ E-journals	10
o Scientific journal articles	
▪ "Scholarly" websites	9
▪ GMU databases	8
▪ "Google" search engine	5
▪ "Google Scholar"	3
▪ "Website" where instructor posts guides and handouts	3
▪ "University website or government website"	1
▪ "Google Docs"	1
▪ Online tutorials on "Excel" (videos, written)	1
▪ Online encyclopedias	1
▪ Writing center websites across the country	1

Note. Based primarily on student interview, Q14: "Did you consult any resources in order to write your lab reports?" and Q15: "What resource did you find most helpful when you wrote your lab reports?"

Assessing teaching strategies.

In this section, I present categories of codes related to students *assessing teaching strategies*: students assessing piecemeal strategy; Biology 213: Cell Structure and Function; Biology 308: Foundations of Ecology and Evolution; Biology 311: General Genetics; and diverse teaching methods and styles. These codes represent how students see the teaching strategies instructors practice when they teach the lab report in the lab courses that students take.

Table 3.25

Students Assessing Piecemeal Strategy

Code	Number of Participants
▪ Piecemeal	12
▪ Piece by piece construction	12
▪ Expectations were clear	12
▪ Entire report due at end	12
▪ Spreads lab report out over time	12
▪ Helpful strategy	10
▪ Makes experience less overwhelming	10
▪ Allows for revisions before final submission	10
▪ Final report influenced by teacher comments	10
▪ Feedback on each section separately	10
▪ Very clear feedback	9
▪ Enhances understanding	9
▪ Teacher fully teaches each section of lab report (IMRAD)	8
▪ Teacher edits and grades each section	7
▪ Final feedback on the whole	6
▪ PowerPoint presentations	5
▪ Prevents procrastination	5
▪ Focus on formatting, citation style	4
▪ Coordination between lecture, lab, and recitation	3
▪ "Recitation TA" taught the writing	3
▪ Modeling a professional journal	3
▪ Gives wrong impression of IMRAD as distinct pieces	2
▪ Gives too much help to students	2
▪ Redundant, slow, boring	1
▪ Controlled, artificial, unrealistic	1

Note. Based primarily on student interview, Q13: "Tell me about the instruction on lab report writing that you received in your laboratory courses, especially in biology;" and Q17: "To what degree do you think your lab instructor/TA feels responsible to help you with your writing? How often do they proofread or edit your work?"

Table 3.26

Biology 213: Cell Structure and Function

Code	Number of Participants
▪ Biology 213	8
▪ Piecemeal reserved for formal report	8
▪ Specific instructions	8
▪ Turn it in by section	8
▪ Comments given on returned sections	7
▪ Students read teacher comments and make corrections	7
▪ Learning from mistakes	6
▪ Prevents procrastination	5
▪ Teacher told students specific criteria for each section before due dates	5
▪ Grading purpose	4
▪ Collaboration	4
▪ "Introduction" completed first	4
▪ "Data" section completed second	4
▪ "Conclusion and Discussion" completed third	4
▪ Assembly of lab report completed fourth	4
▪ Did it in 4 different sections	3
▪ "Editing" and "peer review process" (group report)	3
▪ "Every part we got told how to fix it"	1
▪ Group lab report: "4 people writing 1 lab report"	1
▪ Group lab report is "copying and pasting" data from individual reports	1
▪ "Most intense, most detailed, and most lengthy lab report"	1
▪ "3 week long process" = impressive	1

Note. Based primarily on student interview, Q13: "Tell me about the instruction on lab report writing that you received in your laboratory courses, especially in biology;" and Q17: "To what degree do you think your lab instructor/TA feels responsible to help you with your writing? How often do they proofread or edit your work?"

Table 3.27

Biology 308: Foundations of Ecology and Evolution

Code	Number of Participants
▪ Biology 308	5
▪ Piecemeal construction of journal article	5
▪ Graded sections	5
▪ Comments on each section	5
▪ Allows for revision	5
▪ Professional lab report	4
▪ Recitation: focuses on writing based on lab work	4
▪ Imitates a "peer reviewed journal"	3
▪ Lab, recitation, lecture	3
▪ Coordination between lab and recitation	3
▪ IMRAD structure	3
▪ "3000 word paper" in "professional journal" format	1

Note. Based primarily on student interview, Q13: "Tell me about the instruction on lab report writing that you received in your laboratory courses, especially in biology;" and Q17: "To what degree do you think your lab instructor/TA feels responsible to help you with your writing? How often do they proofread or edit your work?"

Table 3.28

Biology 311: General Genetics

Code	Number of Participants
▪ Biology 311	4
▪ Took whole semester	4
▪ Section by section	4
▪ Each section "graded" and returned	4
▪ Instructor feedback and comments	4
▪ Mitigates negative impact on grade	4
▪ Final report due at the end	3
▪ Opportunity to correct mistakes	2
▪ Applying revisions	2
▪ "Fly lab report"	2
▪ Identifying errors early	1
▪ "Awesome"	1
▪ Doing a "really big report" in "chunks"	1

Note. Based primarily on student interview, Q13: "Tell me about the instruction on lab report writing that you received in your laboratory courses, especially in biology;" and Q17: "To what degree do you think your lab instructor/TA feels responsible to help you with your writing? How often do they proofread or edit your work?"

Table 3.29

Diverse Teaching Methods and Styles

Code	Number of Participants
▪ All teachers are different	15
▪ Not all TAs give sample lab reports	12
▪ Some teachers tell students to "proofread" and "review"	10
▪ Biology assigns "worksheets" as lab reports o Introductory courses (only informal) o Mid-level courses (mixed with formal)	9
▪ First few minutes of class: teacher discusses common errors to class	5
▪ Instructor stays after lab session to answer student questions	4
▪ Oral instructions by instructor during class o Student's responsibility to remember	3
▪ Some instructors send out e-mails to students clarifying instructions	3
▪ Some instructions written "on the board"	2
▪ Instruction: both written and oral o Responsible for both	2
▪ Teacher advice: "Look at rubric"	1
▪ Teacher advice: Do peer collaboration	1

Note. Based primarily on student interview, Q13: "Tell me about the instruction on lab report writing that you received in your laboratory courses, especially in biology;" and Q17: "To what degree do you think your lab instructor/TA feels responsible to help you with your writing? How often do they proofread or edit your work?"

Identifying challenges and problems.

In this section, I present categories of codes related to students *identifying challenges and problems*: negative affect, expectation dissonance, questioning teacher ethics, inadequate assessment, and resisting the rhetorical situation. These codes represent how students interpret the difficulties they encounter when they do lab reports.

Table 3.30

Negative Affect

Code	Number of Participants
▪ Frustration	18
▪ Struggle	17
▪ Doubtful, uncertain (level of detail, what topics to address)	16
▪ Inexperience	15
▪ Overwhelming, stressful	15
▪ Feeling lost	12
▪ Confused (forced to make assumptions)	10
▪ Anxious	7
▪ Fearful, scared	6
▪ "Intimidated"	5
▪ "Terrible"	4
▪ "Annoying"	4
▪ "Hated"	3
▪ "Blind" (first lab report)	3
▪ Guilty (making mistakes)	3
▪ Dislikes writing	3
▪ Cynical (only for a grade)	2
▪ Complaining	2
▪ "Tedious," redundant	2
▪ Feeling "isolated" doing lab reports	2
▪ Unfamiliar with resources	1
▪ Feeling "bitter" about teacher idiosyncrasies	1
▪ "Freaking out" (effect on grades)	1
▪ "Not enjoyable"	1
▪ Feeling discouraged by too many comments	1

Note. Based primarily on student interview, Q1: "Tell me about your experiences writing science lab reports;" and Q2: "Do you remember your first experience writing a science lab report in college?"

Table 3.31

Expectation Dissonance

Code	Number of Participants
▪ Teachers make assumptions o Students can learn very quickly o Students already aware of all university resources o Students already know how to use "Excel" o Students know specialized knowledge	19
▪ Students make assumptions o Teacher's role	19
▪ Oversimplified instructions	17
▪ Poor instructors o Do not elaborate o Cannot understand them	16
▪ Poor instructions set student up for failure	8
▪ Sample lab report not realistic o Not commensurate to expectations o Too complex, reflects professional work o Misleading sample lab report o Wrong impression of what level to write o Inappropriate for novices	8
▪ Hasn't learned genre yet: o New kind of writing o Not familiar o Uncomfortable o Not natural, have to learn it	6
• Not well-coordinated between lab and lecture	4
▪ Intervention only when students do terribly o Basic guidelines provided	3

(Table 3.31 continues)

Table 3.31 continued

Code	Number of Participants
▪ Office hours only once per week o Inconvenient	2
▪ Teacher not telling expectations = "playing games"	1

Note. Based primarily on student interview, Q1: "Tell me about your experiences writing science lab reports;" and Q2: "Do you remember your first experience writing a science lab report in college?"

Table 3.32

Questioning Teacher Ethics

Code	Number of Participants
▪ Lab reports harder because instructions and expectations are unclear	15
▪ Lack of instructor empathy	7
▪ Instructor is irresponsible o Not providing adequate instructions o Sees student as a statistic	6
▪ Instructors mistrust students	5
▪ Instructors make excuses o Too busy o No time	4
▪ Not all instructors have office hours o Schedule an appointment	2
▪ Unhelpful instructor: "figure it out yourself"	1
▪ Unethical teaching practices o Teachers "trick" students into doing the wrong thing	1
▪ Haphazard, impromptu instructions	1
▪ Instructor uses coercion to get students to follow directions o "You're going to have points taken off"	1
▪ "Worst part": lack of directions	1
▪ "Barebones" instruction o Barest essential instructions	1

Note. Based primarily on student interview, Q1: "Tell me about your experiences writing science lab reports;" and Q2: "Do you remember your first experience writing a science lab report in college?"

Table 3.33

Inadequate Assessment

Code	Number of Participants
▪ Unfair grading practices	16
▪ Instructors preoccupied with minor details (grammar, format)	13
▪ Poor commentary: sparse o Doesn't tell you how to improve o Doesn't tell you why something is wrong o Not specific enough o Not constructive o Infrequent	10
▪ Not all comments are helpful	5
▪ Nitpicky grading	5
▪ Lack of consensus among instructors regarding grading o "Inconsistent" grading	4
▪ "Unfair" when instructor doesn't return lab reports in timely manner	2
▪ Instructors are hesitant to help because it will affect grades o Incentive to give students lower grades	2
▪ Illegible comments on reports	1

Note. Based primarily on student interview, Q1: "Tell me about your experiences writing science lab reports;" and Q2: "Do you remember your first experience writing a science lab report in college?"

Table 3.34

Resisting the Rhetorical Situation

Code	Number of Participants
▪ Balancing individual comprehension with teacher as audience o Writing for own learning o Subordinating own interests in order to address teacher's	3
▪ "You're not supposed to mess up"	1
▪ Have to be dishonest o Conceal error in order to get good grade o Graded for correct and accurate data	1

Note. Based primarily on student interview, Q1: "Tell me about your experiences writing science lab reports;" and Q2: "Do you remember your first experience writing a science lab report in college?"

Student-suggested remedies and solutions.

In this section, I present categories of codes related to *student-suggested remedies and solutions*: mitigating negative affect, modifying instruction, modifying assessment, refining resources, and suggested new resources. These codes represent suggestions by students on how to improve teaching and learning strategies of the lab report.

Table 3.35

Mitigating Negative Affect

Code	Number of Participants
▪ Instructor has empathy	10
▪ Instructor inspires students	6
▪ Instructor is responsive, honest	5
▪ Practicing time management	3
▪ Starting on assignments earlier	3

(Table 3.35 continues)

Table 3.35 continued

Code	Number of Participants
▪ Instructor who is "attentive to their e-mail"	3
▪ Knowing teacher idiosyncrasies	3
▪ Knowing expectations early, before due date	3
▪ Teachers should NOT be capricious	2
▪ Timely responses from instructors	2
▪ Developing perseverance	2
▪ Developing determination	2
▪ Instructor encourages "office hours"	1
▪ "Awesome professor" = always willing to answer questions	1
▪ Learning to accept criticism	1

Note. Based primarily on student interview, Q21: "What kinds of writing support do you think should be made available for undergraduate science majors writing lab reports?"

Table 3.36

Modifying Instruction

Code	Number of Participants
▪ Clear, direct instructions	19
▪ Very "specific" and "explicit" instructions	18
▪ Instructor shows, tells, explains	17
▪ Provides sample lab reports	17
▪ Detailed "rubric"	15
▪ Instructor should show students how to use "Microsoft Excel" o Show and demonstrate relevant functions	10
▪ Instructor = Responsible to teach writing	9
▪ Lab report should be explicitly taught	9
▪ Start instruction on lab report early in the semester	8
▪ Instructor takes time to explain sample lab report	7
▪ Instructor asking open-ended questions	5
▪ Instructor should convey instructions in an organized, clear way	5
▪ Regularly communicates	5

(Table 3.36 continues)

Table 3.36 continued

Code	Number of Participants
▪ Standardization (across classes)	4
▪ Coordination between lab, recitation, and lecture	4
▪ Instructor should explain more than once	4
▪ E-mail for communication of expectations	3
▪ Start writing reports freshman year o Worksheets inadequate	3
▪ Instructors should encourage peer review outside of class	3
▪ Modeling lab report writing o Instructor writes lab report with students	2
▪ Intervention for serious language issues (ESL)	2
▪ Uses websites to give explanations	2
▪ "Formula for getting an A"	1

Note. Based primarily on student interview, Q16: "What would you like to know from your lab instructor before writing a lab report?" and Q21: "What kinds of writing support do you think should be made available for undergraduate science majors writing lab reports?"

Table 3.37

Modifying Assessment

Code	Number of Participants
▪ Substantive and constructive comments	18
▪ Quality feedback that elaborates on mistakes	14
▪ Specific comments that TELL students what to do and WHY	13
▪ Less focus on formatting	8
▪ Less focus on grammar	6

Note. Based primarily on student interview, Q16: "What would you like to know from your lab instructor before writing a lab report?" and Q21: "What kinds of writing support do you think should be made available for undergraduate science majors writing lab reports?"

Table 3.38

Refining Resources

Code	Number of Participants
▪ Appropriate and relevant sample lab reports	16
▪ Lab reports commensurate to expectations	12
▪ Teacher should be aware of university resources for writing o Responsible for telling and directing students to resources	5
▪ Relative sample lab reports (superior, average, and poor)	4
▪ Sample lab reports alone are insufficient o Must be explained so student understands	4
▪ "Student to student tutors" o Organized and structured tutoring system	4
▪ More office hours on different days	3
▪ Sample lab report should be "generic" and applicable to any lab report	2
▪ Students should meet only with their instructor, not another o Instructor idiosyncrasies conflict with expectations	2

Note. Based primarily on student interview, Q16: "What would you like to know from your lab instructor before writing a lab report?" and Q21: "What kinds of writing support do you think should be made available for undergraduate science majors writing lab reports?"

Table 3.39

Suggested New Resources

Code	Number of Participants
▪ Tutors at "writing center" that specialize in lab reports	9
▪ Provide "tutorials" or "guidelines" on learning "Excel"	5
▪ An organized peer tutoring center focused on lab reports o Students teaching students	3
▪ Tutorials should be specific, good enough to meet teacher expectations	3
▪ An "electronic" resource for tutoring students on lab reports	2
▪ Establish a Biology Tutoring Center o Focus on biology lab reports o Students can ask questions	2
▪ A one-credit hour course on lab report writing o Required lab-writing seminar (taken early in curriculum)	1

Note. Based primarily on student interview, Q21: "What kinds of writing support do you think should be made available for undergraduate science majors writing lab reports?"

Instructor codes.

In this section, I present codes derived from the data collected via interviews with instructors. See Appendix Q for an excerpt of coding done on a transcript of an instructor interview.

How instructors teach.

In this section, I present categories of codes related to *how instructors teach*: instructors describe piecemeal strategy, teaching philosophy, and transfer. These codes

represent how instructors see themselves when they teach their students about lab reports, and what they believe the implications of their teaching are.

Table 3.40

Instructors Describe Piecemeal Strategy

Coding	Number of Participants
▪ Completed section by section	2
▪ "Overwhelming" to do it all at once	2
▪ Spreading lab report out over time	2
▪ Empathy	2
▪ Final lab reports are "well written"	2
▪ Students have made revisions after initial submissions	2
▪ Indirectly facilitates peer review between student and instructor	2
▪ Prevents procrastination	1
▪ Makes grading "practical"	1
▪ Biology 213: Cell Structure and Function o Piecemeal Strategy ▪ First: "Introduction" ▪ Second: "Materials & Methods" ▪ Third: "Results" ▪ Fourth: "Conclusion, Discussion"	1
▪ Biology 311: Genetics o Formal lab report: Piecemeal strategy o Based on "semester long experiment" o "Not a canned experiment" o "A real mapping experiment" o "Organismal," real	1

Note. Based primarily on instructor interview, Q14: "Have you found it necessary to give 'lessons' on writing lab reports to your students?"

Table 3.41

Teaching Philosophy

Coding	Number of Participants
▪ Purpose of the course is to teach content	7
▪ Retrospective learning exercise	7
▪ The result of "hands-on" activity	6
▪ Instructor not responsible for teaching grammar	5
▪ Teaches "knowing" and "doing" only	5
▪ Students allowed to e-mail lab report for commenting before due date	4
▪ Teaching a derivative of disciplinary activity o Not an isolated act o Social aspects	4
▪ Instructor's job is to stop the errors before they become ingrained or habitual	3
▪ Better instructions provide more detail	3
▪ "Scientific research process" o Students are practicing the scientific method	3
▪ Common assignment in school science o Students have done lab reports before	2
▪ Instruction should be specific o Provide guidance on how to write report	2
▪ Instructors should apply a piecemeal approach if possible o Slows down process	2
▪ Early draft opportunities o Students allowed to hand in drafts before official due date o Instructor provides commentary o No point deductions o Not many students take advantage of draft opportunities o Helps eliminate mistakes early	2
▪ Range of lab reports o Informal: worksheets o Formal: IMRAD	2
▪ Students should be doing more lab reports	2
▪ Teach students how to "interpret"	2

(Table 3.41 continues)

Table 3.41 continued

Coding	Number of Participants
▪ Biology program only teaches writing in "Writing Intensive" (WI) courses	2
▪ Instructors should be direct and straightforward to students	2
▪ Lower quality lab reports o Assigned all at once	2
▪ Responsibility of instructor to provide a lot of commentary during grading o More commentary helps the student	1
▪ WI activities designed for courses with small number of students	1
▪ "Unfair" to give oversimplified instructions that do not specifically convey expectations	1
▪ "Upper division courses" o Focus more on writing o Fewer students per class	1
▪ Students do too many "worksheets" in lab	1
▪ Teaching content knowledge rectifies "writing" problems	1
▪ Doubtful that lab report is taught the same way by all teachers	1
▪ Give students a "crash course" on doing a literature search o Using databases to download scientific journal articles	1
• "Teaching them how to write"	1

Note. Based primarily on instructor interview, Q1: "What do you think the purpose of the lab report is?" and Q2: "Why do you think the lab report is important in college-level lab courses?"

Table 3.42

Transfer

Coding	Number of Participants
• Recording tool: form of documentation	7
▪ Communication tool to other scientists	7
▪ Students are apprentices in training	6
▪ Report should make experiment repeatable and replicable	6
▪ Industrial setting	5
▪ Peer review	5
▪ Journal publication	5
▪ Facilitates entry into discipline	4
▪ Student is part of a large community of scientists	4
▪ Students use same skills to write lab reports that scientists use	3
▪ Rhetorical situation changes	2
▪ Develops cognitive skills	2
▪ Applicable to any field	2
▪ Writing reports for money instead of grades	1
▪ Learning general life skills	1
▪ "Bench scientists"	1
▪ Students only with undergraduate degree will not write journal articles in industry or academia	1
o "Master's program" and "Ph.D. program" required to begin publishing research	

Note. Based primarily on instructor interview, Q3: "How much value do you think the lab report carries in the setting of workplace laboratories?"

Assessment.

In this section, I present categories of codes related to *assessment*: evaluating writing and grading. These codes represent how instructors review, evaluate, and assess the lab reports that students submit to them.

Table 3.43

Evaluating Writing

Coding	Number of Participants
▪ Grammar	7
▪ Content	7
▪ Clear and concise	7
▪ Mechanics	6
▪ Punctuation	5
▪ Formatting	5
▪ Detailed	5
▪ Phrasing	4
▪ Coherence	4
▪ Writing is generalizable skill	4
▪ Paraphrasing	3
▪ "Units"	3
▪ "Citations"	3
▪ "Figure legends"	2
▪ Writing is discipline specific skill	2
▪ "Topic Sentences"	2
▪ "Labels"	1

Note. Based primarily on instructor interview, Q4: "How do you think the lab report should be formatted and/or structured? (e.g. the section names and what order they should be listed);" Q5: "What do you think the features of a satisfactory lab report are?" and Q6: "What do you think the features of an unsatisfactory lab report are?"

Table 3.44

Grading

Coding	Number of Participants
▪ Holistic assessment	7
▪ Instructor is audience	7
▪ Assessment for grading purposes	7
▪ Focus on "content"	7
▪ Uses grading "rubric"	7
▪ Focus on "critical thinking"	6
▪ Grading is weighted	6
o Apportioned by relative difficulty and effort	

(Table 3.44 continues)

Table 3.44 continued

Coding	Number of Participants
▪ "Rubric" focuses on "content" and "grammar"	5
▪ Assignments returned in timely manner	3
▪ Highly organized system of grading	3
▪ Commensurate to a test	2
▪ Rubric varies by class and assignment	2
▪ Comments should not do all the work for students o Comments designed to stimulate thinking	2
▪ "Rubric" focuses only on "content" o No focus on style, grammar, language	2
▪ Rubric uses "points scale"	1
▪ Rubric based on "peer review" process	1
▪ "Explicit rubrics" o Given to both students and TAs	1

Note. Based primarily on instructor interview, Q8: "Do you use a rubric to grade lab reports?" and Q9: "What elements of writing do you focus on the most when evaluating lab reports?

Identifying challenges and problems.

In this section, I present categories of codes related to *identifying challenges and problems*: epistemological disconnect, irresponsibility, cognitive shortcomings, and identifying unsatisfactory writers. These codes represent how instructors perceive why students have difficulty doing lab reports.

Table 3.45

Epistemological Disconnect

Coding	Number of Participants
▪ Disconnecting the "doing" from the "knowing" and the "writing"	6
▪ Foundations of specialized knowledge are very weak	6
▪ A fundamental misunderstanding of concepts	6
▪ Placing info in wrong section	5
▪ Failure to understand why they did the research	4
▪ Don't understand what they were doing	4
▪ Does not recognize they're practicing the scientific method	3
▪ Does not understand why background research is important or relevant	3
▪ Does not understand how lab report sections are interdependent	3
▪ Does not realize they're testing a hypothesis	2
▪ Not seeing connection between their lab report and broader scientific community	2
▪ Not seeing disciplinary connections	2
▪ Wrongly believe that purpose is to report a correct answer	2
▪ "If you don't understand, you can't explain"	1
▪ Seeing science as a validation exercise	1
▪ Seeing science as a cookbook exercise	1
▪ Students assume that obtaining correct data precludes them from explaining the data	1

Note. Based primarily on instructor interview, Q10: "Based on your experience, what elements of lab report writing do you believe students find the most challenging?" and Q11: "When you evaluate lab reports, where do you notice students struggle the most?"

Table 3.46

Irresponsibility

Coding	Number of Participants
• Lack of attention to detail	7
• Not revising	7
• Not editing	7
• Not enough students using “office hours”	6
• Lack of effort	5
• Plagiarism	3
• Procrastination	3
• Not enough students doing draft review process	2
• Not treating assignment seriously	2

Note. Based primarily on instructor interview, Q10: “Based on your experience, what elements of lab report writing do you believe students find the most challenging?” and Q11: “When you evaluate lab reports, where do you notice students struggle the most?”

Table 3.47

Cognitive Shortcomings

Coding	Number of Participants
▪ Oversimplified and superficial analysis	7
▪ Misinterpreting the data	6
▪ Don’t know what results mean	6
▪ Tangents and digressions	6
▪ Not giving “big picture” analysis	3
▪ Student preoccupied with presenting the correct answer	2
▪ Not evaluating hypothesis based on data	2
▪ Students “ramble”	1
▪ “Random facts” presented in “Discussion”	1
▪ “Blah, blah, blah”	1

Note. Based primarily on instructor interview, Q10: “Based on your experience, what elements of lab report writing do you believe students find the most challenging?” and Q11: “When you evaluate lab reports, where do you notice students struggle the most?”

Table 3.48

Identifying Unsatisfactory Writers

Coding	Number of Participants
▪ Difficulties with language	7
▪ "English as a Second Language"	5
▪ Inexperience o Lack of practice	3
▪ "Transfer students" o Not prepared o Missing critical parts of the curriculum o Struggle the most o Includes both domestic and international students	2
▪ Uncommon type of writing	2
▪ "The thoughts are there and they're good, but it's very poor English"	1
▪ Sometimes "completely incomprehensible"	1
▪ "International students" o Make same grammar mistake repeatedly	1
▪ Some students are just "extraordinary writers" o Writing is innate ability o You either have it or you don't	1
▪ Gender gap between students o "Girls do much better than boys" on writing assignments o Girls have better: ▪ "Attention to detail" ▪ Care more about presentation	1
▪ Student preparation limited to English classes in secondary education	1

Note. Based primarily on instructor interview Q12: "How prepared do you think your students are to produce the level of writing required for an undergraduate lab course? Why do you think that is the case?"

Instructor-suggested remedies and solutions.

In this section, I present categories of codes related to *teacher-suggested remedies and solutions*: modifying student learning and instructor intervention strategies. These codes represent suggestions that instructors have for improving the teaching and learning of the lab report through circumscribing the responsibilities of students and instructors.

Table 3.49

Modifying Student Learning

Coding	Number of Participants
▪ Maximize knowledge base	7
▪ Utilize "office hours" more	7
▪ Pay more attention to detail	7
▪ Following "rubric"	7
▪ Following "directions"	7
▪ Following the format	6
▪ Don't procrastinate	6
▪ Students should improve data interpretation skills	5
▪ "Proofread"	4
▪ Doing peer-review outside of class	2

Note. Based primarily on instructor interview, Q13: "Do you provide any resources to your students about writing lab reports?" and Q15: "What are one or two pieces of writing advice you find yourself giving most often to students writing lab reports?"

Table 3.50

Instructor Intervention Strategies

Coding	Number of Participants
▪ Ask students to be specific and explicit when they write	6
▪ Provide constructive feedback	4
▪ Tell students to read lab report out loud to themselves	3
▪ Tell students to ask questions about the meaning	3
▪ Mix positive comments with negative comments	3
▪ Asking WHY questions encourages students to "understand"	2
▪ Early intervention	2
▪ Use Socratic method: o Ask questions that narrow student's focus o Make questions more relevant to student o Questions should be specific	2
▪ Goal is to identify students with major language problems early	2
▪ Student's responsibility to correct language problems outside of class	2
▪ Preventative strategy o Make instructions that identify common errors	2
▪ Empathizes with student difficulties o Realizes that some students have not written reports before	2
▪ "Learning assistant" who focuses on writing	2
▪ "Websites" that offer example lab reports	2
▪ Tell students they are writing for readers "outside of the normal reading audience"	1
▪ Give students "leading questions"	1

(Table 3.50 continues)

Table 3.50 continued

Coding	Number of Participants
▪ Lab report should be taught in context o Cannot be taught separately from a lab course o The "doing" is central to lab report writing o Decontextualize report if writing is taught separately	1
▪ Telling students they shouldn't feel discouraged with having a lot of comments	1
▪ Establish an English class on "science writing"	1

Note. Based primarily on instructor interview, Q12: "How prepared do you think your students are to produce the level of writing required for an undergraduate lab course? Why do you think that is the case?" Q13: "Do you provide any resources to your students about writing lab reports?" and Q15: "What are one or two pieces of writing advice you find yourself giving most often to students writing lab reports?"

In the following chapter, I describe the significance of my results, and analyze, interpret, and draw conclusions from the data in this chapter.

CHAPTER 4: DISCUSSION

In this chapter, I propound conclusions based on the data from the preceding chapter. I address the veracity of the hypotheses I presented in chapter one by comparing them with the data obtained in this study. Specifically, I consider the hypotheses codes stipulated in Table 1.1, and determine whether they are present in the data shown in the results chapter. I demonstrate the strengths of the methodological triangulation by synthesizing the survey and interview results. Once I establish the attitudes, beliefs, and values of students and instructors, I address the mismatch between them. Additionally, I acknowledge similarities in the responses between students and instructors with regard to teaching and learning strategies. Table 3.1 and Table 3.13 indicate that students from each undergraduate level are represented in this study. In this discussion, I demonstrate the importance and relevance of the theories I outlined earlier in my review of the literature by interpreting the results through the theoretical perspectives: genre theory and ZPD. In this chapter, I discuss the following: (a) knowing-doing-writing, (b) genre, and (c) scaffolding.

Knowing-Doing-Writing

In my literature review, I cited an important passage from Carter's (2007) study, which connected ways of knowing with ways of doing and ways of writing. Carter (2007) argued that "the lab experience is a way of doing that is directed toward a way of

knowing. It is primarily in writing the lab report, however, that doing becomes knowing" (p. 388). In this excerpt, Carter (2007) described what a majority of participants felt on both the surveys and interviews. Table 3.3 shows that surveyed students found that the discussion; figures, tables, graphs; organization; and accuracy of data are important. Markedly, these four elements are the result of connecting ways of doing with ways of knowing via writing. Students are unlikely to write a satisfactory lab report unless they first conduct the experiment and possess the specialized knowledge of the discipline. Instructors appear to agree with students, given their survey results on Table 3.7. With instructors focusing on structure, data interpretation, integrating literature, and comprehension, there seems to be a match between what students and instructors value. Writing is the means by which action in the laboratory and specialized knowledge coalesce to reflect an understanding of science.

Since students and instructors had intimated the importance of connecting ways of doing with ways of knowing via writing in the survey results, I decided to pursue this connection further during the interviews. I did this by focusing on students' metacognition. I asked students to think about their mental activities as they wrote lab reports. Metacognition, defined succinctly, is a self-examination of one's thinking or mental processes. Table 3.17 shows that a large proportion of students, 15 out of 19, suggested that ways of doing connect ways of knowing with the act of writing. The actions that students took in the laboratory are central and paramount since those actions prompt students to consider specialized knowledge that is relevant, and to further express that connection in writing. Similarly, in Table 3.41, instructors acknowledged how lab

reports are essentially retrospective learning exercises that are the result of "hands-on" activity. Given the level of agreement that students and instructors have about knowing-doing-writing, there appears to be little, if any, dissonance between the two groups. However, it would be premature to conclude that just because students know the relationship between ways of doing, ways of knowing, and writing, they could successfully demonstrate this connection in their own writing. Although students could explain the connection between knowing, doing, and writing, they had difficulty demonstrating it to their instructors.

Survey results in Table 3.10 show that 11 out of 11 instructors viewed Discussion of Results as an area of difficulty. Perhaps, no section more cohesively connects ways of doing, ways of knowing, and writing more effectively than the Discussion section in a lab report. In the Discussion section, data interpretation takes place through a reexamination of actions committed during the experiment, and an integration of specialized knowledge of the discipline. When there are weaknesses in any of the elements in knowing-doing-writing, problems emerge in the lab report. Table 3.45 indicates six out of seven instructors saw this as a disconnection between the ways of doing, ways of knowing, and writing. I expand on Carter's (2007) model by identifying what could go wrong within and between each way in Figure 4.1.

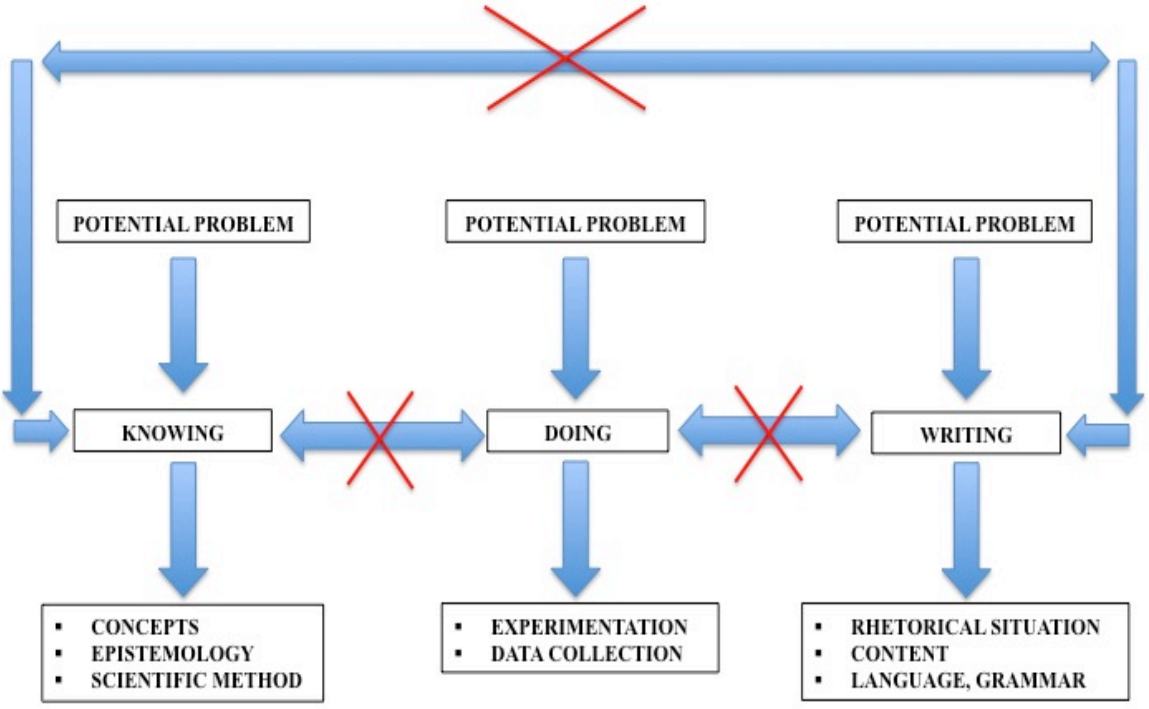

Figure 4.1. Knowing-Doing-Writing model stipulating specific areas of difficulty for students doing undergraduate lab report writing. Specific outcomes in which problems could occur are placed below each element of the model: concepts, epistemology, scientific method, experimentation, data collection, rhetorical situation, content, and language. Demonstrates interrelationships between each element: knowing-doing, doing-writing, and writing-knowing. The red Xs indicate possible disconnections between elements.

Using Carter's (2007) knowing-doing-writing model, I identify areas of difficulty that may explain why students are not meeting teacher expectations. In Figure 4.1, I stipulate specific types of problems that students encounter when they write lab reports. The problems can occur within each element, between elements, or both. I use the term, element, to refer to the knowing, doing, and writing in the figure. Within each element, I provide outcomes that students are expected to master when they do a lab report, such as concepts, experimentation, rhetorical situation, etc. A deficiency in any one of those

outcomes may cause serious difficulties in the completion of the lab report. Between each element, I have drawn a bidirectional arrow that represents the critical thinking necessary to connect the elements together. So, even if each of the elements is strong, the model becomes moot if students do not recognize the interrelationships. The knowing-doing-writing model is analogous to a three-legged table since breaking one or more of the table's legs would certainly cause the entire table to fall apart. Consequently, students would have difficulty completing the lab report with only two elements, and with two or all of the elements missing, the task becomes overwhelming, if not impossible.

In the following sections, I delineate the problems and challenges posed by the elements in the knowing-doing-writing model by identifying the attitudes, beliefs, and values of students and instructors. I mediate the two sides by making recommendations on how to improve the teaching and learning of the lab report.

Knowing: Teaching the discipline's epistemology.

In this section, I discuss the ways of knowing by articulating the perspectives that students and instructors have adopted in the biology discipline. In my review of the literature, I found that ways of knowing are equivalent to disciplinary epistemology, which is itself defined as the ways in which knowledge is created, formed, spread, and articulated in a field of study. Simply put, epistemology is the study of knowledge, and in this particular case, the study of knowledge in biology. As I mentioned in my literature review, Langer (1992) suggested that epistemology is the study of "notions of causality and proof, of evidence or warrants for claims, of assumptions that can be taken

for granted, and of premises that must be made explicit and defended" (p. 71). Langer's (1992) description invites important questions: (a) What constitutes knowledge in a discipline? (b) How are arguments formed in a discipline? (c) Why is knowledge formed and organized the way it is in a discipline? Table 3.2 indicates 40 out of 72 students thought that data analysis is the most challenging aspect of doing a lab report. It is through data analysis that students exercise the discipline's epistemology. When students have difficulty analyzing data, they may have difficulty engaging and practicing the mental processes circumscribed and prescribed by the biology discipline.

Table 3.19 shows 17 out of 19 students thought that by doing lab reports they were demonstrating knowledge. When students were prompted to expand on this, they provided a myriad of disparate explanations, including discussing error, drawing conclusions from data, answering a research question, etc. However, only a small proportion of students could identify that demonstrating knowledge is a process, and even fewer could explain their mental processes for carrying it out. For example, Table 3.17 indicates that most students, 15 out of 19, understood that lab report writing helped them understand the experiment. However, most students neither acknowledged that the lab report is a process for practicing science nor identified their mental processes as playing a significant role when they wrote lab reports. The implication is clear: Students do not view science as a systematic process that is directed and shaped by specialized knowledge.

Student responses, instead, suggest that science is merely an exercise in applying disparate and memorized facts from lecture or their textbook into their lab reports. In this

way, students adopt a cursory and superficial perspective on knowledge since they presuppose that it is neatly prepackaged and ready for application whenever needed. Table 3.22 shows that eight out of 19 students used their textbook as a reference for their lab reports. Table 3.17 shows that only three out of 19 students realized they had to go beyond using their textbook to write their lab reports. For biology lab instructors, this may be a discouraging sign since it means that most students are overly dependent on lecture material, and fail to practice the critical thinking that makes meaning out of the specialized facts they integrate into their lab reports. When science is presented as a set of facts, and the critical connections among those facts are subordinated, it is of little surprise when students attempt to imitate that approach in their lab reports.

Table 3.47 indicates seven out of seven instructors found that a significant problem in lab reports is an oversimplified and superficial analysis. I posit that this problem is directly connected to weaknesses in the ways of knowing among students. I find that in some cases, students may have a fundamental misunderstanding of concepts, and a mischaracterization of science as a static set of facts, as opposed to a dynamic and flexible process. In Figure 4.1, I show that concepts, epistemology, and the scientific method constitute the ways of knowing in science. Students misunderstanding the ways of knowing and instructors identifying oversimplified analysis by students appear to constitute a mismatch between both groups' perceptions of what science is. Table 3.14 indicates that students believe that science is a product to be graded, rather than a process of inquiry. Such a notion is alarming since lab report writing essentially is a process.

Further, since science is a process, so too must be the lab report. The foundations of the process include students possessing a minimum base of specialized knowledge. This includes content from lecture, the textbook, and other sources. Since specialized knowledge can be complex and myriad, students should be especially careful in parsing out the details so that they do not conflate disciplinary terminology. Table 3.19 shows only three out of 19 students acknowledged the importance of distinguishing among the manifold vocabulary in science. Table 3.45 indicates that six out of seven instructors were particularly concerned with the weakness of students' foundations of specialized knowledge. Since students are reluctant to acknowledge this fact, and since instructors have taken marked notice of this weakness, I propose that modifications be made to how instructors teach the ways of knowing.

I postulate that instructors can do this by focusing on two specific outcomes I identified earlier: concepts and the scientific method. Instructors should reframe student perspectives on lab report writing by telling them why conceptual knowledge and the scientific method are relevant to writing lab reports. Instructors may motivate students to correctly remember concepts by simply articulating why doing so in the discipline is important. For example, if key concepts in a lab report include DNA, RNA, and protein, and students conflate the three terms by using them haphazardly, instructors should explain to students the disciplinary consequences of committing such errors. When instructors explain to students that scientists in the discipline exercise accurate and precise usage of key vocabulary terms in order to communicate with other scientists, students may realize that their errors are not as innocuous or inconsequential as they

thought. On the other hand, if instructors decide to motivate students merely by asserting that students' grades would suffer if they use concepts incorrectly, then students would likely just make short term changes as opposed to long term changes, since they would see themselves as fulfilling the requests of an individual instructor, and not of the discipline. When instructors provide context to the specialized knowledge in the discipline, students begin to see why it is relevant to them, and as a result, improve their conceptual connections in lab reports. Although conflating terms may cause conceptual errors, higher order problems remain, which instructors can rectify by explaining the biology discipline's epistemology.

Table 3.30 indicates 18 out of 19 students had at least one experience in which they felt frustrated doing a lab report. Much of that sentiment appears to be a direct result of not knowing how to do a lab report. Table 3.14 indicates 19 out of 19 students found that determining the expectations of the instructor is a primary goal before writing a lab report. I find that at least some of the 19 interviewed students have taken this position since they are unsure of what a lab report is, how and why it is organized the way it is, and why it matters in science in the first place. As Table 3.20 indicates, 11 out of 19 students did not receive adequate preparation before college. Such data suggest that more than half of the students matriculating from high school to college hold very little to no understanding of lab report writing because they did not write lab reports in high school. These numbers should prompt instructors to think about how prepared their students are to do the level of lab report writing they require. Figure 3.4 indicates that instructors thought that students, at best, are only moderately prepared. Certainly, a lack of exposure

and practice on lab report writing are serious but not insurmountable problems. Instructors may mollify student difficulties by teaching and telling students about the biology discipline's epistemology. Further, instructors should explain to students the scientific method, and how it is reflected in the IMRAD structure of the lab report's format. When instructors describe each section, they should also discuss the interrelationships among the sections as well, so that students are not misled to believe that sections function only independently.

Instructors should explain to students that the scientific method is a process. It begins with a hypothesis or research question, transitions into an experimental phase with data collection, and concludes with data analysis and interpretation. The knowing-doing-writing model parallels the scientific method since it establishes how a base of specialized knowledge can be used to form and conduct an experiment, and do a write-up afterwards. Using the knowing-doing-writing model as a guide, instructors could teach the scientific method by adopting my recommendations. First, instructors should articulate to students the importance of accurately understanding the concepts as part of a large disciplinary framework of knowledge. Second, instructors should explain to students that these concepts could be used to test hypotheses and answer research questions. Third, instructors should tell students the role of each section in IMRAD, and any additional sections, such as the literature review and literature cited, and why they're important and relevant. Instructors should extend the lab report's significance to places outside the classroom, such as to the disciplinary setting that professional scientists work in. Further, instructors should tell students that the lab report is a derivation of its

disciplinary progenitor: the scientific or experimental research article. In this way, students may appreciate that lab reports have to be done the way their instructors expect since the instructions are rooted in the discipline, rather than the idiosyncrasies of the instructor. Finally, after providing a holistic perspective of the connection to the discipline, instructors should tell students how the sections in a lab report work together to form meaning.

Table 3.10 indicates that instructors found the Discussion section invariably gives students the most trouble. Instructors should provide special attention to the Discussion section by explaining its relationship with the Results section. Instructors should tell students that the purpose of the Discussion section is to draw conclusions from the data in the Results section. Instructors may offer examples of how to do this by referring to example lab reports. Additionally, instructors could show students how to form scientific arguments by teaching them how to interpret the data from the Results section so that they can form conclusions. Instructors may decide to expand on that lesson by explaining what makes an argument valid in a lab report. Table 3.47 shows six out of seven instructors found that misinterpreting the data is a common error that students make. To reduce this problem, instructors should inform students that their interpretation of the data must be circumscribed by the scientific method and their conceptual knowledge.

When instructors teach students how to think like scientists, they give students the direction and focus they require as neophytes in the discipline. Instructors should teach the epistemology that shapes the discipline: the scientific method. Instructors should

clearly tell students that doing a lab report is enacting the scientific method. In this way, instructors can eliminate and deter preconceptions that inappropriately cast science as a decontextualized and static set of facts. The scientific method encourages students to subordinate the school setting and instead prioritize the mental processes that professional scientists utilize, and hence recognize science as a process and activity that makes meaning out of knowledge. When instructors elucidate the scientific method, they contextualize, clarify, direct, and shape how students do lab reports.

Doing: Relating the experimental phase.

The ways of doing relate primarily to the experimentation that takes place before the actual writing of the report. By the time students conduct their experiment, they should have done the necessary research to understand the experiment and any of the key concepts associated with the topic of the lab. However, such is not always the case since students sometimes do not adequately prepare themselves before conducting the experiment. Most students intimated in the interviews that they did not fully understand all of the concepts in the lab, or what the purpose of the lab was, before conducting the experiment. Students would merely accomplish the experiment that was assigned in the lab manual, and defer the specialized knowledge and critical thinking until they had to write the report they had to submit to their instructor. Table 3.17 indicates that 15 out of 19 students claimed that the lab report clarifies the experiment. I posit that for at least some of the 15 students, the reason may be because they failed to do the preliminary research before conducting the experiment. This appears to connect to Table 3.47, in which six out of seven instructors found that their students are unable to explain what

their data mean. Students consequently procrastinate in learning about the key concepts and research conducted in the field regarding their experiments.

When procrastinating students begin writing their lab reports, they possess data they do not understand and lack the conceptual knowledge necessary to understand the experiment. These students haphazardly put their lab reports together by conflating fundamental concepts, forming erroneous conclusions from the data, and raising a discussion of irrelevant concepts. Student difficulties, therefore, may be the result of procrastination rather than ignorance of the discipline's epistemology. When students conduct an experiment with little to no understanding of what they are doing, they reduce the experiment to a decontextualized act. Given this scenario, students are guided by no concepts and a set of directions that allows them to conduct the experiment without understanding it. As Table 3.46 shows, three out of seven instructors highlighted the problem of procrastination by mentioning that it takes place during the writing stage. I contend that the problem emerges far before the writing stage. Procrastination begins when students are tasked with learning about the concepts and specialized knowledge that shape the direction and understanding of the experiment.

When students conduct an experiment with little background knowledge, it makes it difficult to connect the ways of doing with the ways of knowing and writing. The foundations are tenuous because the ways of knowing are missing, and further deteriorate when lab work to conduct an experiment carry little meaning. By the time students write their reports, they are unlikely to understand what they did, why they did it, or how conceptual knowledge relates to the lab. The knowing-doing-writing model is systematic

since a weakness in one element is likely to cascade and weaken other elements. Instructors can prevent students from isolating and disconnecting the ways of doing from the ways of knowing and writing by casting the lab report as a process, rather than a product. Instructors can tell students that they should complete tasks according to a schedule, and understand that preceding steps function as prerequisites to subsequent steps in the process. Instructors can frame science as a process by depicting the scientific method as a disciplinary heuristic that students should follow. By heuristic, I mean a predetermined model that facilitates the mental processes and understanding sufficient to completing the assignment. In this case, I am referring to IMRAD since it parallels the scientific method. The order, organization, and interdependence of each section indicate that the knowing-doing-writing model is simply not an amalgam of parts, but rather a system.

When students discussed how they conducted experiments during lab, they argued that obtaining accurate data was important since that would ultimately determine their success on the lab report. Table 3.3 shows that 34 out of 72 students, nearly half, contended that correct and accurate data is necessary. Without accurate data, students assumed that their lab reports are inadequate and marginal. Table 3.34 indicates that one out of 19 students confessed to forging and changing data so that it reflects what the instructor expects. This introduces another type of problem that instructors should be aware of. Up to this point, I have pointed to relatively high frequency in my data to corroborate my conclusions. With data manipulation, I take a different approach because it is a serious violation of the scientific method. Although only one student admitted to

doing this, I suspect that most students would rather not confess to committing something they know they're not supposed to do. On such a topic, students are likely to underreport their participation. At the same time, I find that students do not want to present data that they know is wrong, and would prefer to conceal their mistakes in order to avoid point deductions during grading that they perceive as preventable. These students fear that they will be penalized for erroneous results that could simply be rectified by altering their data.

In such instances, these students likely understand the concepts and have done the background research to understand the experiment. Students in these circumstances are likely to view science as a process, and accept and appreciate the scientific method. As a result, these students anticipate what kind of data they should obtain when they conduct their experiment. As students conduct the experiment and record data, some of them may alter data to achieve an ideal outcome that does not represent their own work in the lab. In Table 3.47, at least two out of seven instructors lamented that too many students are preoccupied with reporting correct data. At the same time, six out of seven instructors indicated that misinterpretation of data by students is a problem. Based on these results, I postulate that students mistakenly believe that reporting accurate and correct data solves their problem of misinterpreting data. Students assume that correct data speaks for itself and precludes them from actually doing data analysis and interpretation. This scenario explains why students are so preoccupied with obtaining correct data, and why instructors still identify data misinterpretation as a common problem.

Students believe that correct data is a panacea for erroneous data interpretation. In this way, students are implementing an inappropriate solution to an epistemological problem. Although reporting accurate and correct data may show that students did the experiment correctly, it does not substitute for an explanation of the data in the Discussion. Rather than thinking critically in order to draw conclusions from the data, students have reduced the lab report to a verification activity. In my literature review, I described that Lerner (2007) and Russell (2002) observed that a cookbook or verification perspective emerged in the 20th century. Instead of conducting original research, students had to complete experiments that required them to provide data that matched a predetermined outcome. I find that this trend continues to be true in my own study. When students realize that their data does not match the expectations of the instructor, they are tempted to change the results so that it does. Table 3.14 indicates the importance that students place on meeting teacher expectations with 19 out of 19 students mentioning it.

Instructors may help change student attitudes to discourage data manipulation by telling students how to treat erroneous data. First, instructors should explain to students that it is acceptable to make errors during experimentation that affect the data. Second, instructors should tell students that it is their responsibility to address any erroneous data in the Discussion section. Instructors should acknowledge to students that science is not a flawless activity in which answers are easily discernable. As students conduct their experiments, they may commit errors that distort the data. Fearing a deduction in their grades, some students alter their data to reflect what the teacher expects. Instructors

should alleviate these fears by telling students that their grades would not suffer if they explained and addressed any erroneous data in the Discussion. More importantly, instructors should tell students that obtaining correct and accurate data does not preclude them from providing a meaningful discussion of the data. In this way, students can draw conclusions from the data without fear of being penalized for erroneous data. When instructors explain to students why data manipulation is wrong, they should make epistemological and disciplinary arguments. Instructors should indicate to students that it is not only wrong because it violates the scientific method, but because it also damages their credibility as scientists. For example, in the scientific community, once a scientist is found to have forged or manipulated data, any subsequent work submitted by that scientist is deemed with suspicion.

Instructors and students should realize that through the biology discipline's epistemology, the relevance and importance of the ways of doing are quite clear since they connect the ways of knowing with the act of writing. I discuss the writing process next.

Writing in context.

In my review of the literature, I found that typified rhetorical actions determine the conventions of the discipline. In this way, the experimental article is the progenitor of the lab report. As a teaching and learning tool, instructors assign the lab report in order to teach the discipline to students. Instructors expect students to write lab reports that address relevant topics in a way that matches the discipline's epistemology. In this section, I focus on how students and instructors perceive writing in the biology discipline.

I attempt to find out what students and instructors mean when they refer to *writing*. Table 3.16 shows 17 out of 19 students referred to content when they speak about writing. Additionally, 16 out of 19 students raised the importance of having a clear and concise writing style. Students believe that the content has to be correct and reflect their analysis in a clear and concise way. Similarly, in Table 3.43, seven out of seven instructors indicated that they focus on content when evaluating writing. Table 3.44, which focuses on grading, shows that seven out of seven instructors constructed their rubrics so that they primarily evaluate content overall. Since students and instructors consider content a significant criterion, I find it prudent to determine exactly what they mean when they talk about content.

When students and instructors talk about content, they appear to be referring to the specialized knowledge on which the biology discipline is built. Students learn such specialized knowledge from course lectures, textbooks, and journal articles. Instructors, of course, have far more specialized knowledge relative to students, as a result of their extensive education and careers as scientists and educators. Not knowing basic facts, conflating facts, or not appreciating fundamental principles of the biology discipline are violations of content that instructors observe in student writing. Further, it appears that students and instructors include data interpretation and critical thinking as content. Both groups assume a particular dichotomy in writing: content vs. language. Table 3.16 shows that when students refer to writing, 14 mentioned mechanics, 13 mentioned grammar, and 11 mentioned punctuation. In Table 3.43, seven out of seven instructors considered grammar as an important element in writing. Writing, therefore, is not only about

content, but about the language involved: the grammar, mechanics, punctuation, and style. Given the dichotomy, instructors should articulate to their students and themselves why content and language are essential considerations in lab report writing. I propose that instructors explain why they focus on content and grammar by examining Figure 4.2.

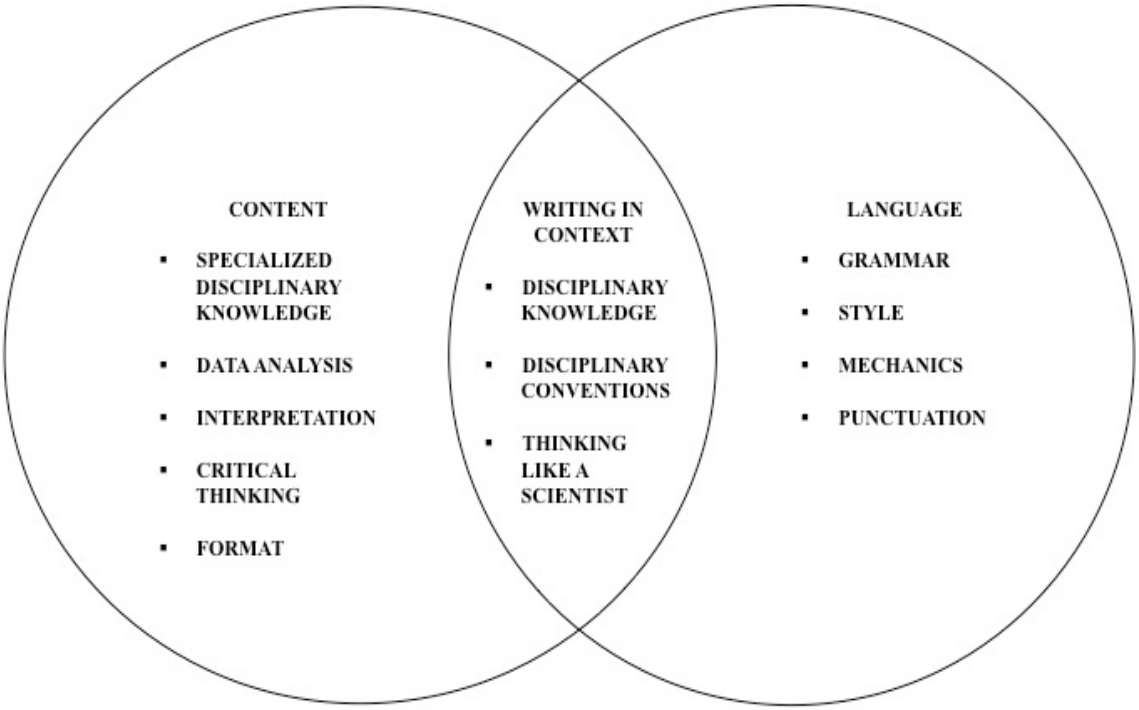

Figure 4.2. Dichotomy of writing in Venn diagram form. Indicates that students and instructors view writing as composed of two separate elements: content and language. The middle portion stipulates the ideal perspective of writing in which content and language coalesce.

Figure 4.2 highlights the dichotomy that students and instructors place on writing. Table 3.9 and Table 3.44 show that instructors focus on both content and grammar when they grade lab reports. By treating the two as separate issues, though, instructors give a misleading impression of writing. When asked which was more important, content or grammar, instructors invariably answered that content was. Language issues, such as grammar, style, mechanics, and punctuation, are assumed to be subsidiary concerns that could be dealt with via the assistance of writing specialists. Consequently, casting the writing as a matter of content vs. language oversimplifies how students perceive the writing. In Table 3.16, nine out of 19 students mentioned that writing is a discipline specific skill, while four out of 19 students mentioned that writing is a generalizable skill. As neophytes in the discipline, students perceive that the writing they do on lab reports is different from the writing they do in other disciplines. For example, students write history papers differently than biology lab reports. The difficult part for students is learning to write in a way that matches the expectations of the discipline and their instructor.

The primary issue, then, is not a matter of content vs. language, but rather a matter of disciplinary writing vs. generalized writing. Students are challenged with using an IMRAD format, formulating scientific arguments, integrating conceptual knowledge and facts, and analyzing and interpreting data. Although students with less experience writing lab reports are likelier to encounter difficulties, any biology major may still face challenges. Instructors often take for granted their familiarity with the discipline's epistemology, specialized knowledge, and writing conventions when they teach students

how to write lab reports. For instructors, writing lab reports has become habitual and routine. When instructors evaluate lab reports written by their students, they notice how markedly students deviate from their disciplinary expectations. In this way, instructors mark errors, provide written comments, and grade accordingly. This, however, is the extent to which instructors typically address the writing. I contend that such an approach provides inadequate direction and explanation to students because instructors have not explicated the discipline's epistemology, or clarified the mental processes that students should practice when writing lab reports.

I posit that changes must be made to the way instructors talk about writing in order to instill substantive and long-lasting improvements in student writing. Instructors should take the initiative to define to students what writing is since they are the leaders and role models in the classroom. When instructors describe writing, they should identify it as a contextualized activity rooted in the discipline's epistemology, specialized knowledge, and writing conventions. Instructors should accept responsibility for teaching the writing that they expect of their students. Instructors should view writing as a total synthesis of content and language. Issues regarding grammar, mechanics, and style cannot simply be exported to instructors in the English department or tutors at the writing center. Biology lab instructors should also play a role in mitigating the language difficulties that students exhibit. One of the first steps instructors should take is to acknowledge and accept that they are asking their students to write in a specialized way. Instructors should articulate this mind-set to students at the beginning of the course. Instructors should understand that their goal is to ask students to write in context, which

is represented by the middle portion of Figure 4.2. To do this, instructors should explain to students how content and language work together to form context. For example, instructors may explain to students how the specialized knowledge taught in lecture was developed due to a community of scientists conducting research, and not by isolated activity.

Instructors may tell students that they are training to become scientists since they are practicing a form of communication that scientists use to discuss their findings with others. As scientists, students should be aware that the scientific community expects them to understand the discipline's specialized knowledge, practice correct grammar, utilize a scientific style, adhere to formatting guidelines, etc. By writing in context, scientists build their ethos, or credibility, as professionals in their discipline. Although students are not professional scientists, they are still taking courses designed to lead to that outcome. As scientists in training, students should understand that they are subject to the expectations of practicing scientists as well. Instructors should impart this perspective to students so that they may understand why conceptual knowledge and grammar are significant in writing lab reports. When instructors consider the time they spend on student writing, they should not believe that that is limited to correcting grammar or punctuation when they evaluate and grade reports. Rather, instructors should realize that they are teaching students how to write when they teach them how to analyze and interpret data, how to integrate conceptual knowledge into their reports, and how to present information concisely. When students write in context, they learn the discipline's epistemology, specialized knowledge, and writing conventions.

Circumstances may arise, though, that cast language problems as the primary concern. Table 3.48 shows that five out of seven instructors found that English as a Second Language (ESL) students generally struggle with grammar and other language issues. In some cases, ESL students understand the concepts, interpret the data correctly, and draw acceptable conclusions from the data, but cannot express themselves without making grammatical or stylistic errors. To assist these students, I posit that at least two steps could be taken. First, instructors should determine exactly what the problem is. Instructors should not generalize among ESL students by immediately determining that these students only have problems with language. ESL students may also have problems understanding the discipline's epistemology, specialized knowledge, and writing conventions. When ESL students have manifold writing problems, instructors should determine what the most critical issue is. For example, when a student has difficulty understanding specialized knowledge and practicing correct grammar, the instructor should clarify any confusion about the specialized knowledge first. When the problem, however, is primarily grammatical or stylistic, instructors should directly and indirectly assist students. Through direct help, instructors should encourage students to schedule a meeting with them so that they can clearly explain to them why they marked grammatical errors and how to prevent them. Through indirect help, instructors should refer students to an outside resource, such as the university writing center. However, instructors should understand that the university writing center is not a panacea for correcting ESL language errors since that is not its primary focus or responsibility (see Kalaskas, 2013, for discussion).

Additionally, instructors should reevaluate how they grade lab reports. Rather than setting aside a fixed number of points assessing grammar or style, instructors should focus exclusively on content. Although some of the instructors already admitted to evaluating writing this way, I posit that there are limits to this approach as well. Incomprehensible language from ESL students may bar instructors from understanding the content of students' lab reports. So, while instructors wish to award credit for the content in a student's lab report, it may be impossible because the language problems are so significant. Varying language proficiencies notwithstanding, the primary goal of students should still be to write in context. To achieve that goal, assistance should be tailored to directly address students' areas of weakness. Instructors should base their assessment of writing on how well students rhetorically convey the content, and not on how many grammatical or stylistic errors students make. Figure 4.2 should remind instructors that writing problems could be of two types: content and/or language. In this way, the Venn diagram is applicable to native English speakers and ESL students since it acknowledges the problems that both may encounter as they write lab reports. Instructors should consider adjusting their grading so that it utilizes writing in context as a guiding principle.

Genre

When I discuss genre, I do so using Miller's (1984) definition: "typified rhetorical actions based in recurrent situations" (p. 159). In this section, I assess the extent to which that definition is true for lab reports as a pedagogical genre, apprenticeship genre, or both. Using the hypotheses I stipulated in my literature review along with the a priori

codes, I intend to show that students and instructors agree that the lab report is both a pedagogical and apprenticeship genre. When I do so, I highlight the advantages and disadvantages that each genre affords when students write lab reports.

Pedagogical genre.

Students believe that the lab report is a schooling or academic genre that is assigned exclusively in science lab courses. Table 3.14 shows 19 out of 19 students acknowledged that lab reports are assigned and done in a classroom and academic setting. All of the interviewed students clearly understood that lab reports are assigned a grade by the course instructor, who they saw as the primary, if not only audience for their report. Table 3.44 indicates that instructors invariably thought lab reports are objects to be evaluated and hence graded. All interviewed instructors acknowledged that their grading reflects a holistic assessment of the student's work. Lab reports constitute coursework that is assigned by instructors, and is therefore circumscribed by due dates and instructions for completion. As an academic assignment, lab reports are contrived in a controlled setting where students are tasked with meeting the expectations of their course instructor. As a teaching and learning tool, the lab report appears to meet the criteria of a pedagogical genre, and hence verifies the first hypothesis I stipulated:

H_1: Instructors and students believe that the lab report is a pedagogical genre designed for teaching and learning purposes.

I find that all of the hypotheses codes I proposed in Table 1.1 are confirmed by the codes I derived from the interviews. Students and instructors did not hesitate in identifying the lab report as a teaching and learning tool that is common in the sciences.

By viewing the lab report as a pedagogical genre, students and instructors concomitantly accept the nuances and niceties of the genre. The rhetorical situation casts students as the writers, instructors as the audience, and the purpose of doing the report as a way to assess, grade, and rank students. Such an understanding subordinates the supposedly primary goal of preparing students for entry into the discipline. The pedagogical genre offers an alternative explanation for assigning lab reports since it acknowledges the setting of the modern university that I had delineated in my literature review. As universities became compartmentalized with disciplines and departments, their student populations grew exponentially. This prompted a need to facilitate learning and evaluation in the classroom for large numbers of students. In the laboratory classroom, lab reports were assigned to fulfill this need, and have since then continued and expanded into the present. When students take a lab course, they understand that they will likely conduct experiments and do lab reports in order to demonstrate knowledge. Lab reports are routine and typical actions between students and instructors. However, just because students and instructors consider them routine, does not mean that they find the process flawless or unproblematic.

When instructors assign lab reports, they believe they have provided adequate instruction and guidance on how to complete them. Students strongly disagree with this contention. Table 3.36 indicates 19 out of 19 students determined that instructions could be more clear and direct, while 18 out of 19 students suggested that instruction should be specific and explicit. Table 3.41 shows only two out of seven instructors mentioned specific instruction as part of their teaching philosophy. The disparity intimates that

students expect a certain degree of instruction and guidance from instructors on doing lab reports. That degree of help, of course, varies from student to student, but overall, all interviewed students suggested that it was the instructor's responsibility to tell students what they wanted to see on lab reports. By placing significant attention on the demands of the instructor, students concede that they are subordinates in the laboratory classroom. On Table 3.18, 17 out of 19 students described that learning the idiosyncrasies of instructors is a part of their process for learning the lab report. Idiosyncrasies, or the individual preferences that set one instructor apart from another, appear to resonate strongly in the academic setting. For example, some instructors are critical of grammar and formatting, while some instructors are critical of data analysis and interpretation.

Students believe that they should first determine what an instructor is primarily critical of. Once they determine the idiosyncrasies, they alter the way they write to meet the instructor's expectations. Additionally, students attempt to closely follow the instructions by reading any guides given by the instructor and by listening to what the instructor has to say about the assignment. Rather than seeing themselves as scientists in training, students consider themselves as disciplinary outsiders who are not in a position to challenge disciplinary insiders, such as the instructor. Such a view reduces science to a simple matter of finding out what the instructor wants, rather than practicing the discipline's epistemology. However, since instructors do not explain the biology discipline's epistemology, I am not surprised that students compensate for this by seeking additional guidance from the instructor.

Students adopt a decontextualized view of lab report writing because they see themselves first as students, and rarely, if ever, as scientists. In this way, students cease practicing science and preoccupy themselves with characteristics of the academic setting, such as their course instructor, assignment directions, due dates, grades, variations from lab to lab, etc. When students label the lab report as a pedagogical genre, they suggest that it is only relevant within the school setting. In my literature review, I mentioned that Berkenkotter and Huckin (1993) considered pedagogical genres as imitations of real disciplinary genres since they contain only "*some* of the textual features and *some* of the conventions of disciplinary genres" (p. 487). While the lab report may not completely reflect the work of professional scientists, it introduces students to the ways of knowing, doing, and writing that are critical prerequisites to disciplinary research. Figure 3.1 shows that pedagogical limitations notwithstanding, students acknowledged by a large margin that the lab report is an important part of college laboratory courses. At the same time, students indicated by a large proportion that they do not like writing science lab reports.

I posit that the differences in the two responses can be explained by comprehending the lab report as a pedagogical genre. Students believe lab reports are important since they are learning tools that elucidate disciplinary knowledge. However, students also dislike doing lab reports because they sometimes cause great harm to their grades, especially when they do not know how to do them. Although considering the lab report as a pedagogical genre acknowledges the setting and circumstances in which it is done, it does little to encourage students to think and act like professional scientists.

Given students' preoccupation with grading, I propose that instructors alter students' perceptions by shifting the focus from short-term goals, such as grades, to long-term goals, such as becoming practicing scientists. To do so, instructors should persuade students to view the lab report as a disciplinary or apprenticeship genre.

Apprenticeship genre.

In my review of the literature, Carter et al. (2007) found that "lab reports appear to encourage *socialization* [emphasis added] into the community of science. That is, they are a way of doing by which students participate in the ways of knowing of that community" (p. 295). However, Table 3.6 shows that this appears to be a view that only a small proportion of instructors mentioned they hold when they teach lab reports. Instructors were more likely than not to cite the lab report's pedagogical value as opposed to its disciplinary value. It was not until I asked instructors to comment on the lab report's connection to workplace laboratories that the topic of apprenticeship genre was raised. Table 3.42 indicates the following: six out of seven instructors considered their students as apprentices, five out of seven suggested that the lab report helps train students for industry work, and all seven acknowledged that the lab report teaches students how scientists communicate with each other in the discipline. Based on this data, it appears that instructors also consider the lab report to be an apprenticeship genre, but not before they call it a pedagogical genre, and not until they are asked to comment on its value as an apprenticeship genre. Students answered questions about genre similarly to instructors. Students were also more likely than not to refer to the lab report's pedagogical value before they spoke about its apprenticeship value. Although Table 3.15

shows 17 out of 19 students found that the lab report prepares them for the workplace, most of those responses were only elicited after I asked them to comment on the degree to which the lab report transfers to workplace labs. In my literature review, I stated the following as my second hypothesis:

> *H_2: Instructors and students believe that the lab report is an apprenticeship genre designed to prepare and train students for work in the discipline.*

Based on a holistic evaluation of the data, I find that this hypothesis remains true, but not to the extent that the first hypothesis does. Students and instructors consider the lab report to be both a pedagogical and apprenticeship genre. The lab report is used as a teaching and learning tool in the school setting, and as a tool to facilitate a transfer of skills and knowledge to the industrial or disciplinary setting. I verify the hypotheses codes listed in Table 1.1 for the apprenticeship genre in Table 3.15 for students and Table 3.42 for instructors since they connect the lab report to the professional setting of a workplace laboratory. Additionally, Figure 3.2 indicates survey results in which a majority of instructors strongly agreed with the position that lab reports prepare students for the workplace. However, because the second hypothesis asks students to consider a setting that they likely have very little to no experience in, I am wary of their responses. Students are exclusively familiar with the school setting of doing lab reports. When students provide answers about workplace labs, they are basing their perspective almost entirely on assumptions. Only one of the students admitted to doing an internship at a professional science lab outside of school. The rest of the students, though, appear to have based their responses on speculation rather than experience.

Table 3.42 corroborates Table 3.15 since it shows that most interviewed instructors agreed with students in considering the lab report as an apprenticeship genre. However, students and instructors are incongruous when they articulate the degree to which lab reports prepare students for the workplace. Table 3.15 shows that nine out of 19 students thought the lab report prepares students for the "real" world or life. What students mean by "real" world appears to be dubious, though, since many could not explain how the lab report facilitates a transfer of knowledge and skills to workplace labs. Students could identify that transfer is possible between academia and disciplinary workplaces, but they struggled to explain how it is possible. Students primarily relied on their lab experiences in the school setting to formulate answers to interview questions. Conversely, instructors explained why the lab report is an apprenticeship genre by drawing on their own experience. Unlike students, instructors have had years of experience working in the discipline, and realize the disciplinary implications of doing lab reports. Given their educational paths to graduate school, I also believe that instructors are more likely to realize the disciplinary implications of doing lab reports early on during their undergraduate education. In this way, the sooner students realize the disciplinary implications of doing lab reports, the more likely they are to understand the lab report as an apprenticeship genre.

Previously, I emphasized the importance of teaching the biology discipline's epistemology so that students could appreciate the contextualized nature of their lab reports. I recommend the same advice regarding lab reports as an apprenticeship genre. The problem is that far too many students and instructors recognize the significance of

the lab report as a pedagogical genre first, and as an apprenticeship genre second. Not only do pedagogical genres emphasize subsidiary concerns, such as grades or teacher idiosyncrasies, they decontextualize the scientific activity by reducing lab reports to "homework." On the other hand, when students and instructors view the lab report as an apprenticeship genre, they contextualize it by emphasizing its disciplinary significance and role in preparing students for the work of practicing scientists. I propose that instructors should reverse the primary perspective on which they view lab reports. Rather than treating lab reports as a pedagogical genre first, they should treat them as an apprenticeship genre first. Instructors should explain to students that when they do lab reports, they are engaging in activities that prepare them for a career as scientists in the discipline. This explanation is reminiscent of the ways of knowing, doing, and writing that I mentioned previously.

Students shouldn't be motivated to do well on lab reports solely because they want a high grade, but rather because they understand their relevance to their careers as future scientists. Ideally, students should see lab reports as preparation and training for work in labs after they graduate. When instructors articulate the disciplinary connection, they contextualize the lab report to students. In this way, short-term goals like grades are subordinated and supplanted by long-term goals, such as a career path to become a scientist. Instructors can motivate students to do lab reports in a way that grading cannot. With this approach, students are likely to find that lab reports are not independent and disparate documents unrelated to one another, but rather related and integral pieces of research constructed by a scientific community. Instructors should be the first to adopt a

view that prioritizes the apprenticeship genre over the pedagogical genre. The change in attitudes, beliefs, and values should take place from the top-down. Instructors may change students' perspectives by telling them about disciplinary implications when they teach lab reports. Students are likely to adopt and follow the perspective of the instructor because they already look to the instructor for advice and guidance. With an apprenticeship perspective, instructors may motivate students to write better lab reports.

In the following section, I discuss the significance of scaffolding among students and instructors.

Scaffolding

In my review of the literature, I adopted Doolittle's (1997) perspective of scaffolding as a way to interpret Vygotsky's ZPD. Doolittle (1997) has said that "scaffolding is a three-component process that consists of (a) presenting a task for student completion that lies at the upper end of the student's zone of proximal development, (b) providing students with the assistance necessary to be successful, and (c) withdrawing the assistance as the student develops in the completion of the task" (p. 97). In this section, I describe how instructors in the biology department facilitate the learning of lab reports by adopting teaching strategies that take into account students' limited exposure and practice doing lab reports. Additionally, I consider the resources that students consult in order to write lab reports. I end by discussing how scaffolding cannot succeed unless empathy is integrated into the teaching strategies of instructors.

Teaching strategies.

When I asked students to tell me about any interesting or unique ways of doing lab reports, they responded by describing how they did lab reports step-by-step for certain experiments in particular lab courses. Such an approach is remarkably identical to the piecemeal approach that I stipulated Berry and Fawkes (2010) had implemented in their science lab classroom. Berry and Fawkes (2010) had apportioned the work of the lab and the lab report over a period of weeks by requesting that students turn in the lab report section by section (p. 58). The piecemeal strategy appears to be exclusive to the biology department at GMU since none of the students indicated that such a practice is done in any other science department. Table 3.25 shows 12 out of 19 students acknowledged that the piecemeal strategy spreads the completion of the lab report out over time. Rather than having the entire lab report due at once, the lab report is apportioned so that particular sections are due on different dates. Table 3.40 shows that at least two of the instructors reported implementing a piecemeal strategy for at least one of the lab reports they assigned. Since the IMRAD structure divides the lab report into four major sections, instructors found that assigning a due date for each major section affords sufficient time to teach the lab report and for students to learn it. With the piecemeal strategy, instructors explain and discuss the purpose of each section before they assign it to students. Following the IMRAD structure, instructors describe and explain to students the significance of the Introduction, Methods, Results, and Discussion. Instructors provide specific guidelines and instructions for each section, and take the time to answer any questions that students have.

The piecemeal strategy allows for intervening comments and revisions. When students turn in a section, it is graded and returned in a timely manner. During the grading process, the instructor writes comments on the reports that point out errors and areas that need improvement. It is expected that students would then use the instructor's comments to make corrections for the final report that is due at the end of the process. The piecemeal strategy is designed to scaffold the learning process to students so that they are not overwhelmed from having the entire lab report due at once. I enumerate five advantages to using the piecemeal strategy. First, when the lab report is spread out over time, students are given an opportunity to reflect on the purpose of the experiment, and to think about how each of the sections works together to make meaning out of the lab. On a practical level, the piecemeal strategy also emphasizes adherence to a timeline, and with that, the responsibility and discipline sufficient to prevent procrastination. Second, instructors are afforded the time to teach students about each section in IMRAD. Specifically, instructors relate the particular experiment students are doing to each section of the report. Third, the piecemeal strategy affords the feedback from instructors that students find almost essential to their success. Table 3.37 indicates that 18 out of 19 students thought that instructors should provide constructive and substantive comments on their lab reports. When lab reports are submitted piecemeal, this allows instructors more time to comment on each section relative to if they were to grade the entire report at once. Hence, the quantity and quality of comments are higher, and satisfy students' inclinations. Fourth, students find that revisions are a typical part of doing lab reports. When instructors return reports to students, they should remind them that experimental

articles by scientists in the discipline undergo multiple rounds of revision as well. By making the disciplinary connection clear, instructors can convince students they are learning the process of doing the lab report, and not just the lab report itself. The process of doing a lab report is a teaching and learning activity, which prepares students for the professional work of the discipline. Finally, doing lab reports piecemeal alleviates the fear that students experience about receiving poor grades. Table 3.30 shows six out of 19 students reported being fearful of the impact that a poorly produced lab report would have on their grades. The piecemeal strategy addresses this concern by slowing down the process of doing lab reports so that students can follow the instructor's feedback to make revisions to each section prior to the submission of the entire report. Table 3.40 indicates that the two instructors who use the piecemeal strategy generally found the final lab reports to be "well written," suggesting that students revised each section according to the written comments of the instructor.

Students described three laboratory courses in the biology department that use the piecemeal strategy: *Biology 213: Cell Structure and Function*; *Biology 308: Foundations of Ecology and Evolution*; and *Biology 311: General Genetics*. Table 3.26 indicates that of the eight students who described Biology 213, all of them found the specific instructions provided via the piecemeal strategy to be helpful. Additionally, students noticed that the comments provided by instructors allowed them to learn from their mistakes. Similarly, Table 3.27 shows that students who took Biology 308 found the piecemeal construction of a scientific journal article, or what they considered to be a professional lab report, to provide sufficient guidance in teaching a genre they had little

experience doing. Table 3.28 indicates that students who took Biology 311 acknowledged how doing a lab report section-by-section allows for opportunities of feedback from the instructor that lead to higher grades. By implementing the piecemeal strategy, instructors teach the lab report in a way that benefits the greatest number of students since it addresses the needs of both weak and advanced students. Granted that there may be a few student detractors who found the piecemeal strategy to be artificial and unrealistic, the majority of students found it helpful, constructive, and effective. Table 3.25 shows that only one out of the 19 interviewed students found the piecemeal strategy to be "boring" and "slow." Students who have limited experience doing lab reports would benefit from the piecemeal strategy the most since it demonstrates to students that the lab report is more of a process than it is a product in and of itself.

In my literature review, I found that Vygotsky (1978) defined the ZPD as "*the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers*" (p. 86). I posit that the piecemeal strategy is flexible enough to operate in the ZPDs of a wide range of students. By building structure and organization into the teaching of the lab report, students are afforded the time, knowledge, practice, and feedback from an instructor who plays the role of a disciplinary expert. The "adult guidance" that Vygotsky (1978) speaks of is crucial since the instructor holds significant influence on inculcating to students the mental processes of a scientist. Without adequate guidance from the instructor, students are likely to rely on mental processes and knowledge that are not part of the discipline.

Table 3.45 shows six out of seven instructors found that disconnecting the ways of knowing, doing, and writing is a critical problem for students who write lab reports. The piecemeal strategy allows instructors to work within the range of students' ZPDs since instructors guide students step-by-step through the scientific method, and thus help students connect the ways of knowing, doing, and writing. Such a strategy integrates multiple points of assistance and feedback before and after each section of the lab report. Before writing each section, students are supplied specific instructions from the instructor. After writing each section, students receive feedback from the instructor.

Although students and instructors find the piecemeal strategy to be effective, I suggest one change. When instructors tell their students about the IMRAD structure of the lab report, they should extend their discussion to the discipline's epistemology. Instructors should not assume that students already understand that science is a process. The fact that several students are unfamiliar with the IMRAD structure should suggest to instructors that students are also unfamiliar with the scientific method. Instructors should clearly reiterate to students what the scientific method is, and should explain how the IMRAD structure is derived from it. Since science experiments are shaped by a disciplinary context, so too must be the lab reports that report the findings. It is fundamental that students adopt a contextualized perspective of IMRAD if they are to understand the lab report as a process. The piecemeal strategy appears to be conducive to teaching the biology discipline's epistemology. The scientific method should be clearly and explicitly taught during the lab report writing process. When instructors provide directions, they should tell students that the lab they are doing is a dynamic process

reflective of the scientific method, and is not a process that is static or decontextualized. In this way, instructors convince students that the lab report they are doing is not only a school assignment, but a way of knowing, doing, and writing that is shaped by the biology discipline. An underlying goal should be to teach students how to think like scientists so that they can put that thinking into practice when they do lab reports.

Forms of assistance.

When students write lab reports, they invariably encounter challenges or problems that require the assistance of their instructors or peers. In this section, I focus on the manifold strategies that students undertake in order to ameliorate or solve difficulties. I continue my discussion of Vygotsky's theory of ZPD by describing the ways that students learn from more knowledgeable others. Given the resources that students consult, I verify the third hypothesis I stipulated in my literature review:

H_3: Instructors teach the lab report by providing various forms of assistance.

It appears that instructors advocate a preventative strategy of assistance in which students rectify errors before they submit their lab reports for grading. Table 1.1 of hypotheses codes for ZPD indicates that four out of the five codes coincide with the preventative strategy: "assistance from teacher," "asking 'leading' questions," "teacher as expert," and "peer collaboration." The one code that is not preventative is "learning from mistakes" since that suggests students have to wait for the instructor to return their graded lab reports in order to examine the instructor's written comments and feedback. In this way, the written comments and feedback on graded lab reports serve as a resource for future labs. Instructors, however, do not view their own written comments and feedback

on graded reports as a resource. Instead, instructors suggested that students seek their help when encountering difficulties doing the lab report before they turned it in for grading. Students could do this by meeting with instructors to ask their questions. Vygotsky (1978) posited that a teacher could go even further in one-on-one meetings by asking "leading questions" to trigger the student's learning (p. 86). Table 3.50 shows two out of seven instructors spoke about how they use the Socratic method to help students when they are stuck. One instructor specifically mentioned the use of "leading questions" as a way to narrow students' focus so that they examine concepts germane to the lab. Table 3.12 and Table 3.49 indicate that instructors encouraged students to engage in peer collaboration outside of class when they had difficulty doing lab reports. Additionally, Table 3.49 shows that instructors thought that students could improve their writing on lab reports if they understood the biology discipline's specialized knowledge better, utilized office hours more, and carefully followed instructions. In this way, instructors believe that students do not ask for help from them as much as they should. Instructors suggest that one of the ideal times to use the Socratic method is during office hours in a one-on-one setting since students can focus directly on the instructor's questions. However, because the students who could benefit from this help do not attend office hours, it is not surprising that those students often do not do as well on lab reports as they would like.

Instructors believe that students have a responsibility to know the specialized knowledge that circumscribes the discipline, and to follow their instructions. Any deviation from the specialized knowledge or instructions represents shortcomings of the

student. Additionally, instructors circumscribe their main responsibilities to what happens during class time, in which they articulate the guidelines of the lab report and describe expectations. Instructors assume that students already understand the specialized knowledge on which the lab is based, and require no further instruction with specialized knowledge. Additionally, both instructors and students suggest that the teaching of specialized knowledge takes place in the lecture portion of the course. What takes place outside of class time is more debatable. Based on the guidelines and resources available, instructors believe that students are sufficiently prepared to write their lab reports. The problem isn't that there aren't enough resources; it is that students are not using the resources afforded to them. For example, by not attending office hours, or not paying attention to instructions regarding the lab report, students are not fulfilling their responsibilities. Student responses explain why they have views that diverge from their instructors. Although Table 3.21 shows 16 out of 19 students considered their own course instructor to be a resource, Table 3.22 reveals only five out of 19 students admitted to attending their instructor's office hours. These results intimate that students use a combination of resources that are inside and outside the course.

When students work on lab reports, they generally consult the resources that are most relevant and readily available. The primary resource that students consider is their lab instructor. Students want to ascertain what the instructor expects on a satisfactory lab report since the instructor is the primary audience of lab reports. However, the interaction between students and instructors is not entirely free or open because instructors cannot reveal the answers to students. Instructors recognize that there is a

difference between assisting students by teaching them to think, and assisting students by giving them the answers. Additionally, the time that instructors are available outside of class is limited to office hours, appointments, and e-mails. The scope and extent of the difficulty the student is facing influences the forum in which to receive help as well, with significant problems dealt with better during office hours and minor problems better solved via e-mail. Students acknowledge that although they believe office hours are useful, they believe it is only useful for *some* students. The reasons for students not attending office hours range from scheduling conflicts to a dislike of the instructor's personality.

The aversion to direct one-on-one interaction with instructors may explain why students rely heavily on indirect means to obtain help from the instructor. For example, Table 3.4 shows 62 out of 72 surveyed students, or 86.1%, considered written comments and feedback on graded lab reports to be a useful resource. Additionally, Table 3.24 indicates 17 out of 19 students have e-mailed their course instructor for help at least once. In both cases, though, the assistance takes on a characteristic of permanence that speaking in a one-on-one setting cannot. Comments and feedback are written down on students' lab reports, and e-mails are saved on students' e-mail accounts. These types of assistance can be referred to easily and quickly simply by reading whatever was written. Conversely, in a one-on-one conversation with an instructor, students have to rely on memory to remember what the instructor said, unless they also wrote down what the instructor said during the conversation. Overall, the data suggest that students prefer assistance that is provided in written form as opposed to spoken form.

Students believe that an instructor's written comments provide insight into what the instructor expects. Table 3.18 shows 14 out of 19 students found that learning lab reports is an iterative process. Students use the written comments to avoid making similar mistakes on future lab reports. In this way, students may need at least a few attempts at writing lab reports before they are satisfactory to the instructor. One survey participant described succinctly, "Written comments and feedback on graded lab reports helped the most because it allowed for the TA to say what needed to be added or corrected. This made it easier when writing the next report to see what changes needed to be made." It appears that the primary purpose of written comments is to point out errors to the student. Accordingly, students refer to their previous lab reports with comments to guide how they write their subsequent reports. Students want instructors to be honest and straightforward with them by telling them what they are doing wrong. The comments on graded reports come the closest to representing this approach.

Other written forms of assistance include sample lab reports and scientific e-journal articles. Table 3.5 shows 64 out of 72 surveyed students, or 88.9%, perceived that a sample lab report could assist them on doing their own lab reports. Table 3.22 indicates 16 out of 19 students used sample lab reports as a guide. Additionally, Table 3.24 shows 10 out of 19 students utilized scientific e-journal articles when they were having difficulty. Both sample lab reports and e-journal articles constitute written forms of assistance that help students understand concepts and visualize the organization of a lab report. Sample lab reports serve as models and templates on which students can base their own reports. Table 3.38 indicates that students found sample lab reports most

effective when they are commensurate to the expectations of the instructor. Students who are unfamiliar with lab reports may find sample lab reports markedly helpful since they tell them what the foundational sections of the lab report are. When students use e-journal articles as sources for their own lab reports, they attempt to locate those that are germane to the content of their own report. Students read e-journal articles in order to find key concepts they should discuss in their lab report and to observe how data is displayed in tables and figures. However, without perspective, sample lab reports and e-journal articles are limited in their assistance to students.

Although sample lab reports and e-journal articles show students what goes into a lab report, they do not articulate how they were written or why they were written the way they were. Instructors can make up for this shortfall by explaining and modeling the writing process to students. In addition to explaining how the scientific method shapes the IMRAD structure, instructors should write the lab report along with their students. Instructors can *model* the steps in their decision making process as they write the report. For example, when drawing conclusions from the data, instructors can demonstrate to students how they refer to the Results section to analyze and interpret the data. In this way, they show students that drawing conclusions from the data requires a preceding step of data analysis and interpretation. In another example, instructors may show students how to display their data in figures and tables as opposed to text. Instructors could take that as an opportunity to teach students how to use software to construct tables and graphs. When instructors distribute resources to students, they cannot do so simply assuming that students will know how to use them. Scaffolding cannot work unless

instructors do their part to demonstrate the relevance of the resource to their students' work. Instructors should take the time to explain why sample lab reports and e-journal articles are helpful by showing them how they would use them.

Perhaps, the resource that students and instructors referred upon the most is the rubric. Table 3.8 shows 9 out of 11 surveyed instructors used a rubric to evaluate and grade lab reports. Table 3.5 indicates that 62 out of the 72 surveyed students, or 86.1%, found that they would do better on lab reports if given a rubric that was clear, detailed, and specific. Similarly, Table 3.49 shows that seven out of seven instructors thought that students would do better if they followed the lab report's rubric. Students and instructors, however, disagree on the degree to which the instructor's rubric is helpful. Instructors believe their rubrics provide enough guidance and instruction, whereas students contend that instructors do not provide enough. Although students consult the rubrics, they find them to be unclear or vague, and thus of limited assistance. Instructors may assist students by evaluating and reviewing the rubrics they use. If the rubric is sparse with detail and does not include an enumeration of basic content that should be addressed or stipulated, it is most likely to be of limited use to students. When instructors develop their rubrics, they should consider telling students what tables, figures, or graphs they should include in the Results, and what concepts they should address in the Discussion. Additionally, instructors may consider providing some leading questions on the rubric that direct, guide, and narrow the focus of students so that only relevant material is addressed. Instructors should scaffold the teaching and learning process so that they tell students how to think about the lab. Since students lack the practice and experience of

doing lab reports, instructors should remind themselves that the details they often take for granted are significant to students.

In the section on knowing-doing-writing, I provided a macro-perspective of doing science lab reports by describing the discipline's epistemology. In this way, I emphasized how instructors should articulate the mental processes students should engage in, and how students should adopt a perspective of themselves as scientists. In this section, I provide a micro-perspective by discussing the series of decisions that students make to learn the lab report. For students, obtaining resources in written form is a priority. Such resources include written comments on graded lab reports, e-mails, sample lab reports, e-journal articles, and rubrics. Given the likelihood that students have busy schedules consisting of multiple classes, it is not surprising that they rely on resources that can be consulted at any point in time. Students are drawn to these written forms of assistance since they realize that instructors are available in-person primarily during class time or office hours. To use class time or office hours most effectively, students have to know what they want to ask. It generally turns out, however, that students aren't ready to ask their questions by those times. Consequently, students turn to written forms of assistance when they cannot reach the instructor. Additionally, students often turn to each other for help. Table 3.4 shows 45 out of 72 surveyed students, or 62.5%, sought advice from other students. Similarly, Table 3.21 shows 12 out of 19 students collaborated with their peers outside of class. Scaffolding works most effectively when a more knowledgeable peer helps those with weaker development in their ZPDs. However, even if the students working together all have similar levels of

development in their ZPDs, the collaboration may still help since students exchange ideas, and in that process possibly formulate solutions they could not have done alone. Only a small proportion of instructors mentioned peer collaboration as a strategy that students should consider outside of the classroom. Table 3.12 shows two out of the 11 surveyed instructors were receptive to peer collaboration. Similarly, Table 3.49 shows two out of the seven interviewed instructors recommended doing peer-review outside of class.

When I define peer collaboration, I also consider peer review as an equivalent term. In this way, any activity involving a discussion among students about challenges or problems doing the lab report constitutes peer collaboration. I stipulate these details because when I asked students to describe peer collaboration, they said that it takes place while they write lab reports and after they write them. On the other hand, instructors thought that peer collaboration takes place after, and therefore constitutes a review. In either case, though, students seek the assistance of other students to improve their lab report. After students write their reports, they ask others to read over them and comment on them. Based on the data, it appears that students did not limit themselves in asking help from students in their own classes. Students sought help from other students in their major, students outside their major, and family and friends outside of the university. Instructors may find some relief in knowing that students are taking the initiative to peer review amongst themselves. Given the limited time afforded in lab, instructors have to prioritize the course activities. Consequently, peer review often is not part of the course, unless the course is writing intensive.

For the courses in which peer review is not mandated, instructors should consider telling students to do peer review outside of class. Instructors could facilitate this by forming peer review groups, which would be required to meet periodically. To ensure that students are doing peer review, instructors could ask students to submit a short report that reflects on what happened during the peer review. Peer collaboration or peer review provides an alternative means of assistance that the written forms of assistance cannot. When students listen to and speak with each other, they solve problems by exchanging ideas. Collaboration often takes place when people with a common goal and purpose come together to solve a problem. For students, it is an opportunity to learn from one another and teach one another. Additionally, because students see each other as equals, they are more likely to be open and honest with each other relative to the formal interaction they have with their instructors. When instructors are not available, peer collaboration appears to constitute a strong alternative. In this way, instructors should emphasize to students the value of peer collaboration. Instructors may make connections to disciplinary activity by telling students that scientists regularly work with other scientists and review each other's reports. When students realize that doing peer collaboration and review are activities ingrained in the discipline, they may adopt them as learning strategies.

Empathy.

I end this section on scaffolding by addressing the relevance of empathy. Empathy is the "action of understanding, being aware of, being sensitive to, and vicariously experiencing the feelings, thoughts, and experience of another of either the

past or present without having the feelings, thoughts, and experience fully communicated in an objectively explicit manner" (*Merriam-Webster's online dictionary*, 2013). In this section, I explain how empathy plays a significant role in the development of students' ZPDs. When Vygotsky (1978) introduced the idea of the ZPD, he did so with the assumption that instructors would consider it their responsibility to assist students. Part of that assumption includes the idea of empathy since by assisting students, instructors would identify with students' weaknesses. Instructors would accept that students do not have the expert knowledge they do, and would therefore implement teaching strategies that facilitate learning in the classroom. The teaching strategies that instructors would use would be formed out of an understanding of what the student already knows and what he or she seeks to know. Vygotsky's ZPD theory is a social-psychological theory that asks instructors to imagine themselves in the place of the student. One of the reasons why instructors do not adopt this theory is because it implies that they must take on more responsibility and a larger role in assisting students. For example, in the case of lab reports, instructors would have to determine how prepared students are and formulate teaching strategies that address students' weaknesses. Fortunately, the Department of Biology at GMU has already taken steps in this direction, particularly through the use of a piecemeal strategy in teaching lab reports. While students find this strategy helpful and effective, I still find that additional steps could be taken to create a learning environment conducive to ZPD theory.

When I interviewed students, I found that far too many of them suggest their self-worth is tied to grades. Table 3.14 shows all 19 interviewed students suggested that

grades are a primary reason for doing lab reports. When students spoke about lab reports, they asserted that earning points on the assignment is central to their success. Consequently, I am led to conclude that students equate themselves with the number of points they receive on a report. Such self-assessment is discouraging given the fact that lab reports are supposed to serve as training for disciplinary activity. When students think of grades first and specialized training second, they conflate the order in which they should perceive the lab reports they do. Instructors do little to mollify this sentiment by tying the grading to a presentation of the discipline's epistemology. Table 3.9 shows that the components of the rubrics are a breakdown of the IMRAD structure: Introduction, Methods, Results, and Discussion. Therefore, when students are asked to think about the scientific method, they are also asked to think about the grading of the report. When the lab report becomes defined and entrenched by grading guidelines, it becomes difficult to remember that its primary purpose is to help train students for disciplinary activity. Table 3.30 shows 18 out of 19 students admitted to frustration and struggle when they write lab reports. I posit that instructors can reduce this by deemphasizing the focus on grading when they speak to students. The less instructors talk about grades, the less students will bring them up.

Once instructors realize that a focus on grading is insufficient to motivate students to do better on lab reports, they will have accomplished an important step in adopting a teaching philosophy circumscribed by empathy. Although deemphasizing grades may alleviate some of the pressure on students, it does not directly address the frustration, struggle, and uncertainty that students experience. By ascertaining why students struggle

with lab reports, instructors may develop strategies to improve lab report writing. Instructors may do this by determining the level of preparation students have from high school. Figure 3.1 shows by a significant proportion that students did not feel that high school prepared them to write lab reports in college. The results on Table 3.20 are more encouraging with eight out of 19 students admitting that high school helped to some degree. Of those who said it helped, a majority had taken a college equivalent course, such as Advanced Placement (AP), International Baccalaureate (IB), or dual enrollment. Figure 3.4 shows that instructors did not believe that their students were fully prepared when they entered their lab courses. With students acknowledging their own lack of preparation and instructors taking notice of that fact, it appears that instructors could take on a more empathetic role for students.

However, based on Table 3.31, Table 3.32, and Table 3.33, this does not appear to be the case. Table 3.31 shows 19 out of 19 students suggested instructors make too many assumptions about what students know regarding lab report writing. For example, students repeatedly pointed out that instructors thought students knew how to use the basic functions of Microsoft Excel to make graphs and do calculations, when the opposite was in fact true. Table 3.32 shows 15 out of 19 students suggested that instructors intentionally distribute vague instructions. Such a claim also intimates that instructors are aware of students' difficulties, but are doing little to assuage them. Finally, Table 3.33 indicates 10 out of 19 students found the written comments on lab reports to be poor because they are cursory and infrequent. In this way, these tables provide reasons for why students feel frustrated learning about the lab report. When instructors make too

many assumptions about their students, they deviate from ZPD, scaffolding, and empathy since they are more interested in carrying out course objectives, rather than balancing objectives with the abilities of their students. For example, when an instructor skips over a lesson they perceive to be minor, such as how to use Microsoft Excel, it may cause significant frustration to students who have never used that software before. Instructors should not assume that students have done lab reports prior to college or that they have used the software commonly associated with lab reports. Additionally, instructors should not assume that students could learn how to do lab reports quickly, given that it is a multifaceted and interdependent process.

Before students begin the process of writing a lab report, instructors should help them by providing directions that are detailed and specific. After students submit the reports for grading, instructors should continue to help students by providing substantive and constructive commentary. With this approach, instructors work toward eliminating the assumptions they hold of students. Instructors should not expect that a student who has little practice doing lab reports could figure out how to write a satisfactory lab report based on an IMRAD template and a rubric with few details. Instructors should scaffold the process of doing lab reports in order to integrate students into the discipline. In order to alleviate the frustration that students experience, instructors should reconsider why they believe students produce unsatisfactory lab reports. Table 3.46 shows seven out of seven instructors found that a lack of attention to detail is the reason students do poorly, which implies a lack of revision and editing. However, such conclusions may only conceal deeper problems, such as conceptual misunderstandings, misapprehending the

scientific method, or not understanding the purpose of each section in the report. Such problems are difficult to detect since the discipline's epistemology is only assumed and not articulated in the lab report itself. In order to assist students with their difficulties in doing lab reports, instructors should ascertain the root causes of the problem by asking students why they think they are not doing well on their lab reports. In this way, instructors may find that they had been correct, that it was a lack of attention to detail. However, I contend that it is more likely that students do not understand what their instructors say because instructors have made too many assumptions about what students already know.

When instructors empathize with their students, they should consider that students might have different lab instructors who have different guidelines for writing lab reports. Table 3.29 indicates 15 out of 19 students already noticed this. Instructors should take note of the different ways that their colleagues teach the lab report in order to determine the different ways that students learn it. While different teaching strategies may not constitute a large issue to instructors, it does to students. When students enter a lab course and are asked to write lab reports, they are not only relying on the instruction and guidance given by their course instructor, but on their own past experiences of writing lab reports as well. Over time, students may notice that the guidelines they receive from one instructor may directly conflict with another. For example, one student responding to the survey said, "Every professor has their own style and expectations when it comes to lab reports. What works for one professor may not work for another." Instructors can proactively address this issue by telling students that within the biology discipline,

variety and flexibility are allowed among instructors as long as it does not alter the discipline's epistemology. In this way, issues such as grammar or formatting can be adjusted according to the preferences of the instructor. Since biology is a discipline shaped by specialized knowledge and the scientific method, instructors should not deviate from those principles when they evaluate lab reports. When instructors anticipate and identify problems that students may encounter, they can address students' concerns by basing their response on the discipline's epistemology. In this way, instructors can avoid giving cursory responses, which simply tell students to dismiss the way other instructors teach the lab report, and adopt their method instead.

Students recognize when instructors shape their teaching strategies around empathy. Table 3.35 shows 10 out of 19 students suggested that empathy reduces the level of frustration they experience. How to achieve empathy, though, remains a multifaceted challenge, given the differences among students. What may be true for one student may not be true for another. However, by looking for trends in the data, I may propose recommendations for teaching strategies. Figure 3.1 shows that a large proportion of students found their instructor to be responsible for teaching writing. Instructors appear to agree with students based on the data in Figure 3.3. By simply acknowledging that it is their responsibility to teach students how to write lab reports, instructors do something significant for students. Instructors elucidate to students the perspective that the lab report is a special type of writing reserved for the sciences. In this way, students realize that the lab report is a genre tied to the discipline that cannot be exported to writing classes outside of the sciences. So, rather than determining that it is

their English instructor's responsibility to help with their writing of lab reports, students recognize that it is their lab instructor who they should seek help from.

When lab instructors stipulate their responsibilities to their students, they should tell students how much help they should expect on certain areas. For example, if lab instructors state that they are not responsible for teaching grammar, students who consider this a challenge realize they will have to consult resources outside of the course. Students mentioned that instructors often take this as an opportunity to recommend university resources. Table 3.23 indicates that the university writing center is a resource that students have considered. What students find, though, is that the writing center provides limited assistance, given their lack of specialized knowledge and lack of familiarity with the lab report genre. In this way, students who have used the writing center find that tutors limit their help to language related issues, such as grammar and mechanics. For students who are experiencing difficulty solely with language, the writing center may be of significant help. However, for those who are having difficulty understanding the lab report as a genre and the discipline's epistemology, it appears that the course instructor is a better resource. When instructors refer students to outside resources, they should make sure that they understand how those resources may help students. Simply referring any student to the writing center is not an effective strategy. Instructors should first determine exactly what the problem is. From there, they should evaluate the resources they recommend to their students. In the case of the writing center, instructors may find that it is less helpful than they initially anticipated.

When instructors empathize with students, they identify the weaknesses of their students and develop strategies that call attention to those areas. Table 3.11 shows that instructors understand that students are inexperienced in writing lab reports. The effort to inculcate students on lab report writing should not be limited to a single strategy. It also should not remain static and unchanging. Instructors should constantly adapt their teaching strategies to address the weaknesses of their students. With so many different students comes the likelihood of a myriad of different problems. The most effective strategy would address the needs and concerns of students, and perhaps integrate recommendations from students into teaching strategies as well. Table 3.39 shows nine out of 19 students would like to see tutors at the writing center who specialize in scientific writing, and specifically, lab report writing. Additionally, five out of 19 students intimated they would consider seeking the help of tutors who teach Microsoft Excel. Although instructors have little control over what happens at the writing center, they can still take into account what students mean when they say they want to consult a tutor. Students are seeking help in a one-on-one setting in which they can speak directly with a more knowledgeable other over a period of time to address any weaknesses in their writing or technological abilities.

Instructors may integrate teaching strategies that closely resemble the tutoring scenario students envision. For example, instructors could integrate peer review both inside and outside of the class setting. Instructors may facilitate this by providing a set of guidelines, which tells students how to do peer review and why it is important. If rubrics are given, instructors could connect those to the peer review by making them the criteria

by which students evaluate other students' lab reports. During the peer review process, technological issues could also be addressed. Instructors should tell students that it is acceptable to help each other learn software that they are unfamiliar with. In this way, the process of teaching and learning the lab report extends outside of the classroom. When students teach other students, instructors spread the responsibility for teaching and learning to all those involved. Since the effort becomes collective, an overall improvement in lab report writing is likely to occur over time among the students majoring in the biology discipline.

FUTURE RESEARCH DIRECTION

As a pilot study, this thesis opens new doors to research that heretofore were unrealized. Each of the codes I generated from the survey and interview data may be used as variables for experimentation in future studies. For example, students and instructors raised peer collaboration as an activity associated with lab report writing. A future study could examine the peer review process to evaluate its relative effectiveness by correlating time spent on peer review and grades earned. With regard to written comments left by instructors on graded lab reports, a discourse analysis could be done to directly identify and elucidate their purpose and significance. Sample lab reports distributed by instructors and utilized by students could also be examined through discourse analysis. Additionally, a discourse analysis could be conducted on the rubrics that instructors use to evaluate lab reports in order to provide another perspective on which to ascertain the attitudes, beliefs, and values of instructors. When instructors teach students how to write lab reports, a naturalistic study could be conducted to directly observe instructors and students in the classroom setting as the teaching and learning take place. Such a study may be most amenable to one of the three courses that utilizes a piecemeal teaching strategy: Biology 213: Cell Structure and Function; Biology 308: Foundations of Ecology and Evolution; and Biology 311: General Genetics. Further, a longitudinal study could be conducted to trace the development of a biology major doing

lab reports over an extended period of time, such as from freshman to senior year. In such a study, a think aloud protocol could be utilized to provide insight on what students are thinking as they write their reports.

I admit that the data collected in my study raise as many questions as they answer. Future studies may conduct a similar experiment and focus on the differences between the variables that emerge. For example, a qualitative study may be conducted that identifies whether class level differences have any impact on the attitudes, beliefs, and values that students have regarding lab report writing. Such a study would aim to determine the relative differences among freshman, sophomore, junior, and senior biology majors. When instructors spoke about resources they recommend to students, they often stipulated the university writing center. A qualitative study could be conducted, which follows up on the relationship between the biology department and the tutors at the writing center. In this way, a study may triangulate between instructors and tutors to determine the extent to which the writing center can assist biology majors writing lab reports. Additionally, because this thesis prompted students to think about their experiences writing lab reports before college and how they anticipate writing lab reports after college, I posit that qualitative studies may be conducted that investigate the settings most associated with those experiences. In this way, qualitative studies may take place on high school students and teachers, and on professional scientists in the workplace, which ask them to comment on the attitudes, beliefs, and values they have regarding lab report writing in college. Such an approach may elucidate how students experience lab report writing outside of the college setting.

Although this thesis focuses only on the Department of Biology at George Mason University, its methods are still certainly applicable to other science departments. For example, this exact study could be conducted on the chemistry department or physics department. Such a study would determine whether different departments teach the lab report differently, and how and why they would do so. A more extensive study may triangulate between the departments to identify differences and similarities regarding teaching and learning strategies. Further, the methods of this thesis could be applied to different types of universities: private, public, community college, Ivy League, for-profit, rural, urban, or liberal arts. Given that GMU is a suburban university with a diverse student population, those factors may have influenced the results. If this study's methods are applied to a science department at another university, the results may likely differ. In a large-scale study, comparisons may be made between the attitudes, beliefs, and values regarding lab report writing among the students and instructors at different types of universities. Additionally, future studies may compare variables that explain why certain students do better on lab report writing than others. Such studies may investigate how factors such as language proficiency, culture, race, gender, and other background characteristics affect how students learn to write lab reports.

APPENDICES

APPENDIX A: EXCERPT OF COURSE LABORATORY MANUAL

Writing a Lab Report

Introduction

An important aspect of understanding the process of science is to understand how information gathered via the scientific method is used to arrive at conclusions and how it is documented and communicated to other members of the scientific community. For working scientists, the documentation and communication aspects are usually accomplished by publishing papers in peer-reviewed scientific journals and presenting these papers orally at scientific conferences.

Students will be exposed to both of these aspects of the process of science by preparing individual formal written lab reports about a lab activity conducted during the course.

Although students worked in their lab groups to carry out the assigned activity, each student must prepare his/her own lab report. The written lab reports will be submitted electronically and lab instructors will be checking to make sure that each student has submitted an original report. In the sections that follow, instructions are provided on the required format and content of the written lab report. A grading rubric may be provided by your lab instructor so that students know in advance how the written lab report will be graded. All written lab reports must be submitted electronically by the due date. Your lab instructor will notify you of the due date and will explain the electronic submission process.

During the last meeting of the lab class for the semester, each group may also be required to present an oral report summarizing the experiment about which the lab report was written. If this is assigned, the oral report must be supported by a PowerPoint presentation and all members of the group must participate in the preparation and delivery of this presentation.

The portion of the lab grade that will be based on the individual written lab report and group presentation can be found in the lab syllabus.

Instructions for Written Lab Report

General Format

The lab report should be written in the passive voice, not in first person. For example, instead of saying "I added soil to the column…," you would say "Soil was added to the column…."

There is no minimum or maximum length for the lab report. The goal is to say everything that must and should be said as concisely. As a result, there is no incentive for students to alter font or margin sizes to stretch the report to some pre-determined minimum length. A 12 point font should be used along with margins that are 1" on the top and bottom of the page and 1.25" on the left and right sides of the page.

The lab report must contain a cover page that lists the title of the lab, centered left to right and top to bottom. Centered at the bottom of the cover page, each on its own line, will be your name, the date of submission, your lab instructor's name, and your lab section number.

The next page will contain the abstract, which should be single-spaced, with the section heading centered above it.

The remainder of the lab report will begin on the next page. You should not start a new page for each new section, except for the literature cited section, which should begin on a page of its own.

The section name should appear, centered on the page, prior to the start of each section.

The introduction, methods, results, and discussion sections should be double spaced. The citation on the literature cited page should be arranged in alphabetical order by author, singled-spaced within a citation, double-spaced between citations, with a hanging indent of 0.5."

The lab reports must be submitted electronically as an MS Word document.

The written lab report must contain the following items/sections:

- Title
- Abstract
- Introduction
- Methods
- Results
- Discussion
- Literature Cited

You can go to http://www.wisc.edu/writing/Handbook/ScienceReport.html for a good, concise guide to writing lab reports.

Each of these items/sections will be discussed below and an example of most will be provided.

Title

The lab report must have a **title** and the title must be descriptive of the experiment. It is not appropriate to title a lab report "Lab Report" or "Winogradsky Column Experiment"! The title should appear on a cover page, mid-way down and centered. At the bottom of the cover page, centered, you should place your name, your lab instructor's name, your lab section number, and the date of submission.

In italics below is a sample title:

The Effects of Aerially Applied Diflubenzuron on Decomposition Rate and Litter Arthropods in Prince William County, Virginia

Abstract

The first section of the written lab report should be the **abstract**. It can be challenging to write a thorough but concise abstract. The length of the abstract should be no more than one page and ideally should be shorter than one page.

Although it will appear first, it is sometimes suggested that it be written last. The abstract is a miniature version of the lab report. Its purpose is to provide potential readers of the report (or article in a scientific journal) enough information about the experiment to decide whether or not they should read the entire report. Obviously, the material in the abstract should be presented in the same order in which it will be encountered in the lab report.

The abstract should be on a page by itself, following the title page and before the next page, which will begin with the introduction. An abstract sample is not provided here.

Introduction

The **Introduction** section of the lab report "introduces" the reader to the experiment. The problem or issue being studied must be described. Background information on this problem/issue must be provided. This requires doing some research into the problem/issue and providing a summary of the key information. This background information should also familiarize the reader with

the topic. The source of the background information must be cited in the body of the introduction section. All sources cited must be compiled in the "Literature Cited" section. For this report, students must cite literature from three sources in their introduction section.

The introduction must include a brief description of the experiment and a statement of the **hypotheses**. In order for your statement about your hypothesis to be complete, it needs to include a statement about an **observation** that you expect to make, as well as an **inference** explaining why you think it will occur.

The section in italics below is an incomplete excerpt from an introduction section:

Introduction

The purpose of the research described here was to evaluate the effects of repeated applications of diflubenzuron on the decomposition rate of leaf litter and on non-target arthropods residing in the leaf litter.

Since litter arthropods play an important role in the decomposition of leaf litter, significant changes in litter arthropod populations as a result of diflubenzuron applications should be reflected in changes in leaf litter decomposition rates.

Methods

The **Methods** section of the lab report should contain an explanation, in paragraph format, of the procedures that were carried out to test the hypotheses in the experiment. Do not provide a bulleted list of the materials used and/or a bulleted or numbered list of the steps taken to carry out the experiment.

Don't be mislead or confused by the "materials" and "procedure" sections of most of the lab exercises in *this* lab manual. The "materials" needed for each exercise are provided in a list for ease in setting up the exercise and obtaining the necessary supplies and equipment. Since most of the exercises in this book are not being designed by the student, the "procedure" section presents the steps necessary for carrying out the exercise in a numbered list so that the majority of students using this manual will be able to carry out the unfamiliar activities.

The person reading your lab report should be able to carry out the experiment exactly the way you did based on your written methods. If the reader is confused, then you have not written the methods properly or clearly.

The reader also needs to know why you carried out the steps and processes. For example, a study that investigated the effects of a medication on liver function might have involved 100 people. The report might have stated, "The liver function of 100 people was tested after they had taken the medication for four months." But for a reader or scientist wanting to replicate the experiment, it would be important to know at least the ages and genders of the human subjects. Obviously, using 100 10-year-old males in such a study would produce very different results than using 100 80-year-old males or 100 50-year-old females. It would be clearer for the lab report to include a more descriptive

statement that also included a reason, such as "This study used 50 men and 50 women, all of which were 50 years old, so that all subjects were the same age and so that both genders were equally represented."

As you describe your procedures make sure you include all of the materials you used and the quantity of each material used. Provide additional detail about the materials when it is necessary and pertinent. In this Winogradsky column experiment, plastic tubes were used. For reader or someone wanting to replicate the experiment it would be important to know that the plastic tubes were clear (reason: so that changes in the microbial growth could be observed) and the size of tube used. It is also important to indicate in this section what data will be collected, when it will be collected, and how it will be analyzed.

The section in italics below is an excerpt from a methods section.

Methods

Three study areas were selected from mixed oak-hickory deciduous forests. Two study areas in western Prince William County had been treated for gypsy moth with diflubenzuron 3 years and 5 years, respectively. The third study area, in eastern Fauquier County, served as the control because it had never been treated with diflubenzuron. Table 3 summarizes the diflubenzuron treatment histories of the study areas.

Leaf litter was collected from each of the 10 sample sites within each of the three study areas on each sampling date. The litter sampling location at each site was varied in a random manner from one sampling date to the next. When a litter sample was taken, the metal stake, serving as a permanent marker for the plot, was located. Random compass coordinates and a random number between 1 and 5 were generated using a random numbers table. The litter sample location was selected by moving away from the permanent marker a distance of 1 m to 5 m in a compass direction, as indicated by the random numbers table.

All leaf litter, including the first 10 mm of soil, was gathered from a 0.25 m^2 area and placed in a (15 cm by 46 cm) plastic sample bag until the bag was approximately ¾ full. To allow ventilation, the bags were loosely sealed by twisting the open end and securing with a metal twist tie. Each sample bag was labeled to identify sample location and date.

Results

The **results** section consists of a written portion as well as either a graph or a table that summarizes the data collected in the experiment.

In the written portion you should state the summary values for key data (such as mean, mode, median, range). You do not need to write out every bit of data collected. You should not make any

interpretation of your data in this section!

If there is a trend in the data it should be described. A trend is a verbal summary of a relationship between two variables. The following are examples of trend descriptions:

- *The average number of trees chewed on by beavers increased the closer the trees were to the water.*
- *In our sample of 50 people, those that had children all indicated more headaches than those without children.*

All of your data must summarized in either table or graph form. It is not necessary to present the same data in both a graph and a table. You should choose and use whichever of the two provides the best summary/illustration of your results. Each graph must be labeled with the word "Figure" followed by a number. The first graph would be labeled "Figure 1," the second graph would be "Figure 2," etc. Each table is labeled with the word "Table" followed by a number. The first table would be labeled "Table 1," the second table would be "Table 2," etc. Since you want the reader to look at your graphs/tables, you must alert the reader to their presence in the lab report by referencing them in the results section. Every graph and table must be referenced individually in this section. An example of a reference follows:

- *See Figure 1 for all tree data.*

All graphs and tables must have a thoroughly descriptive title in addition to the "Figure" or "Table" label. The title must include both the dependent and the independent variables and should immediately follow the figure/table label. Examples of graph and table labels and titles follow:

- *Figure 1. Mean distance from the water (in meters) of chewed and not-chewed trees selected by beavers.*
- *Table 1. Selection frequency of trees by beavers based on tree species.*

Both the x- and y-axis of graphs must be labeled with both the name of the parameter being graphed on that axis and the units that were used. Also, you must make sure that you place the correct variable on the appropriate axis. The dependent variable goes on the y-axis and the independent variable goes on the x-axis.

The section in italics below is an excerpt from a results section.

Results

Isopoda were more abundant at the control site than at either of the spray sites on 3 of the 9 sampling dates. More Isopoda were collected at the 3-year spray sites than at the control or 5-year spray sites on 4 dates. The largest Isopoda collection was 18 individuals on 18 May 1992. The smallest collection was 2 individuals on 6 May 1993.

Discussion

The discussion section must include a restatement of your hypotheses. And remember that the hypotheses must include an observation and an inference.

In the discussion section you must state your conclusion as to whether or not the data supported each of your hypotheses. You should never use the words "proved" or "disproved." Data

collected in an experiment can only support or not support a hypothesis. The data, in summary form, that led to your conclusion must also be restated in the discussion section.

If your hypothesis was not supported, you must attempt in this section to explain why by providing at least one alternative explanation for your results. Was there an error in the experiment? Did you not control all the variables?

If your hypothesis was supported, you must state at least one alternative explanation for why your hypothesis was supported. In other words, is there a variable that may not have been controlled for that could be the reason the data supported the hypothesis?

The discussion section is where you should pose new questions that have arisen as a result of this experiment and to formulate new hypotheses.

This is the only section of the lab report in which you interpret your data. In every other section you are only presenting facts. In this section you should explore and discuss your observations, data, and conclusions.

The section in italics below is an excerpt from a discussion section.

Discussion

The expected result of this study was that, since diflubenzuron adversely affects arthropods, arthropod abundance in the 3-year and the 5-year spray sites would be reduced relative to the control site. The results of this study, however, do not demonstrate such an affect. In fact, the results support an opposite scenario: a greater abundance of litter arthropods in the spray sites relative to the control site. Table 33 summarizes the dates on which the 3-year or the 5-year spray sites had a greater arthropod abundance than the control site, presented by taxon and date. Litter arthropod abundance was greater in the spray sites than in the control site in 53.7% of the comparisons, and significantly greater in 17.5% of those comparisons.

Gypsy moth infested areas that are not treated to suppress the gypsy moths are likely to experience episodes of canopy defoliation (USDA 1995). Such defoliation can alter the microhabitat of the forest litter by altering its moisture content and temperature (Schowalter and Sabin 1991, Neumann 1991). Alteration of the forest litter microhabitat can, in turn, lead to changes in litter arthropod abundance (Badejo and Straalen 1993, Schowalter and Sabin 1991, Bird and Chatarpaul 1988, MacKay et al. 1986, Vats and Handa 1988). In this study, a possible explanation for the greater abundance of litter arthropods in the spray sites than in the control site is that the effects of gypsy moth infestation on the canopy in the control site resulted in an alteration of the forest litter microhabitat

that did not favor litter arthropods (such as a decrease in moisture content and an increase in temperature). In theory, the repeated treatment with diflubenzuron of the gypsy moth infestations in the 3-year and 5-year spray sites preserved the canopy, which in turn preserved the litter microhabitat that favored litter arthropods (such as higher moisture content and lower temperature) (USDA 1995).

Literature Cited

If a scientist were preparing a paper to be submitted to a scientific journal for publication he/she would consult that publication in advance to determine which citation format to use. Your lab instructor will inform you of the citation format that you are required to use in your lab report.

You are required to cite literature from three sources in the introduction section of your lab report. You must indicate in the body of the lab report when you are citing literature by giving the author's last name followed by the publication date or copyright date (not separated by commas) in parentheses immediately after stating the pertinent information. For example:

Spider populations are adversely affected by multiple-year application of diflubenzuron (Largen 2000).

In the "literature cited" section at the end of the lab report you must list, in alphabetical order by author, the works that you actually cited in the body of the report. Examples of the format for listing literature cited follow:

Uetz, G. W. 1974. A method or measuring habitat space in studies of hardwood forest litter arthropods. Environ. Entomol. 3: 313-315.

Borror, D. J., C. A. Triplehorn, and N. F. Johnson. 1989. An introduction to the study of insects, 6th edition. Saunders College Publishing of Holt, Rinehart and Winston, Inc., Orlando, FL. 875 pp.

APPENDIX B: STUDENT LAB REPORT (EXAMPLE #1)

Effects of Pollutants and Sugar Presence on Rate of Cellular Respiration of Yeast

Abstract

Experiments were conducted on dry active yeast to determine how certain conditions or factors influence the rate of cellular respiration. Goals of the experiment consisted of verifying the importance of carbohydrates in cellular respiration and the effects of pollutants on cellular respiration rates. The rate of cellular respiration was calculated by observing carbon dioxide production. The results revealed that sugar shows great significance in cellular respiration and pollutants can decrease the rate of this process. The culture tube without a presence of sugar produced no carbon dioxide and the culture tubes with simulated pollutants had little or no carbon dioxide production except for the culture tube with a bleach pollutant. Carbohydrates are necessary for abundant ATP production and several pollutants can greatly lower this production for organisms.

Introduction

Cellular respiration is an essential process used by all living organisms. This is a process where oxygen and glucose are used to produce water, carbon dioxide and adenosine triphosphate (ATP) (Carter, 2010). The ATP produced is energy currency that both eukaryotes and prokaryotes use to survive (Bailey, 2013). Dry active yeast was used to test how different factors affected the rates of cellular respiration. Yeast was an ideal choice because it is a simple organism and is affordable. The first hypothesis is that yeast will have a higher rate of cellular respiration with the presence of a carbohydrate than yeast without a carbohydrate. The second hypothesis is that yeast with carbohydrates will have a lower rate of cellular respiration if simulated pollutants are present. The six simulated pollutants used were isopropyl alcohol, vinegar, salt solution (10%), baking soda solution (5%), bleach solution (1%), and soap solution (10%). These specific pollutants were chosen because they are often used by people everyday. In application to the real world, pollution is present nearly everywhere. People often pollute areas by throwing bottles and dumping excess chemicals. Dumping of chemicals can occur when humans pour household chemicals like bleach down sink drains. These chemicals will eventually end up in bodies of water such as lakes and can result in pollution. In areas where organism health is poor may be because of pollution hindering cellular respiration, by lowering the amount of ATP produced. Using and testing the simulated pollutants can help determine which pollutants are most detrimental to organisms. Because one product of cellular respiration is carbon dioxide, the rate of cellular respiration can be measured by the amount of carbon dioxide released (Largen 2008). The main objective was to

determine how certain factors affected the rate of cellular respiration and to also test the importance of sugar presence.

Methods

Eight 15 mL culture tubes were used to test the rate of cellular respiration of dry active yeast. Along with dry active yeast, granulated sugar and warm tap water were also used. The simulated pollutants used were isopropyl alcohol, vinegar, salt solution (10%), baking soda solution (5%), bleach solution (1%), and soap solution (10%). For the first culture tube, 1 mL of dry active yeast was added into the culture tube. Using a 15 mL graduated cylinder, 13 mL of warm tap water was poured into the culture tube. The next step consisted of thoroughly mixing the contents by holding the culture tube, placing a thumb on the opening, and then shaking vigorously. The mixture appeared fairly uniform; some specks of dry active yeast were still visible. A clear vial was then used to cover the opening of the first culture tube. The culture tube of Yeast+Water was then inverted and left undisturbed. Immediately after inverting the culture tube, another empty 15 mL culture tube was placed next to the first culture tube in the same orientation. The empty culture tube was used to measure the amount of gas volume production by looking at the changing liquid surface level. The liquid surface level was recorded every minute for 10 minutes. These steps were repeated for the second culture tube. However, 1.25 mL of granulated sugar was first mixed with the 1 mL of dry active yeast in a 25 mL beaker. The beaker contents were then transferred to the second culture tube. Then, 13 mL of warm tap water to the second culture tube. The remaining six culture tubes required simulated pollutants. For the third culture tube, 1 mL of dry active yeast and 1.25 mL of

granulated sugar was also added into a 25 mL beaker. 10 mL of warm tap water was then added to the beaker. These steps for the third culture tube were repeated for the remaining culture tubes. Afterward, 3 mL of a specific simulated pollutant was mixed into each beaker, and the contents were then transferred to a empty 15 mL culture tube. Each of the six groups in class were assigned to a certain simulated pollutant to add. In the end, each of the six culture tubes contained a different simulated pollutant; not one of the remaining six culture tubes had the same simulated pollutant. The culture tubes with pollutants were then covered with vials, inverted and left undisturbed. These six culture tubes were observed and carbon dioxide output was recorded every minute for 10 minutes by each group. Each group then wrote their specific pollutant data on the chalkboard for the entire class to use. For the first culture tube of Yeast+Water, rate of cellular respiration was calculated by dividing total carbon dioxide production by 10 minutes. The calculation step was repeated for the remaining seven culture tubes and the rates were recorded in Table 3 below.

Results

The volume of carbon dioxide produced varied greatly from each of the eight culture tubes. According to Table 1, the culture tube with yeast, sugar and warm water had a high carbon dioxide output at 3 mL in 10 minutes when compared to the Yeast+Water culture tube. Yeast+Water produced 0 mL of carbon dioxide in the same amount of time. The second culture tube of Yeast+Sugar+Water had a high output of carbon dioxide because all necessary reactants of cellular respiration were present. In the equation of cellular respiration, glucose and oxygen are necessary reactants that

eventually yield to water, carbon dioxide and ATP. In the case with simulated pollutants, isopropyl alcohol and baking soda caused the dry active yeast to yield 0 mL of carbon dioxide. Except for Yeast+Water+Sugar+Bleach Solution, the culture tubes with pollutants had carbon dioxide production less than 1 mL in 10 minutes. The culture tube with bleach solution produced the same amount of carbon dioxide as the Yeast+Water+Sugar culture tube.

Table 1. The amount of CO_2 produced by cellular respiration for each culture tube measured every minute for 10 minutes.

Tube	Gas Volume (mL) in Culture Tube at Time (min)										
Contents	0	1	2	3	4	5	6	7	8	9	10
Yeast+ Water	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Yeast+Sugar+ Water	4	4	4.5	5	5	5.5	5.5	6	6	6.5	7

Table 2. The amount of CO_2 produced by cellular respiration for each culture tube with simulated pollutants added measured every minute for 10 minutes.

Simulated Pollutant	Gas Volume (mL) in Culture Tube at Time (min)										
	0	1	2	3	4	5	6	7	8	9	10
Isopropyl alcohol	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25
Vinegar	2	2	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.75
Salt Solution, 10%	3	3.25	3.5	3.5	3.4	3.6	3.5	3.5	3.5	3.5	3.5
Baking soda solution, 5%	5.5	5.5	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.5	5.5
Bleach solution, 1%	2.5	3	3	3.5	3.5	4	4	4.5	4.5	5	5.5
Soap solution, 10%	3.5	3.6	3.6	3.6	3.7	3.8	3.9	3.9	3.9	3.9	3.9

Table 3. Total CO_2 production by cellular respiration and rate of cellular respiration for each of the eight culture tubes.

Tube Contents	Total Volume of CO_2 Produced (mL)	Cellular Respiration Rate (mL/min)
Yeast+Water	0	0
Yeast+Water+Sugar	3	0.3
Yeast+Water+Sugar+Isopropyl alcohol	0	0
Yeast+Water+Sugar+Vinegar	0.75	0.8
Yeast+Water+Sugar+Salt solution, 10%	0.5	0.05
Yeast+Water+Sugar+Baking soda solution, 5%	0	0
Yeast+Water+Sugar+Bleach solution, 1%	3	0.3
Yeast+Water+Sugar+Soap solution, 10%	0.4	0.04

Discussion

Cellular respiration rates in living organism will be higher if there is a presence of carbohydrates. Rates of cellular respiration will be lower if pollutants are present and if carbohydrates are absent. The Yeast+Water+Sugar culture tube had a high production of carbon dioxide at 3 mL, which supported the first hypothesis. The culture tube of Yeast+Water had 0 mL of carbon dioxide production. The rate was 0 mL/min because there was no sugar present in the culture tube. Carbohydrates are necessary for cellular respiration; these sugars are essential reactants in cellular respiration because they store energy within their chemical bonds. For the last six culture tubes, Table 3 revealed that the presence of pollutants will reduce the rate of cellular respiration except for bleach solution. Most of the pollutants supported the second hypothesis; all but one pollutant lowered the rate of cellular respiration even though a carbohydrate was present. According to Table 3, there was a rate of 0 mL/min for the culture tubes with isopropyl alcohol and baking soda, indicating no cellular respiration. For these two culture tubes, the pollutants did not reduce cellular respiration rate, but actually prevented it from occurring. Vinegar, salt solution and soap solution were the pollutants that significantly lowered rates of cellular respiration for dry active yeast. According to Table 2, these three pollutants caused carbon dioxide production to be less than 1 mL in 10 minutes. The only pollutant that did not reduce cellular respiration was the bleach solution. According to Table 3, the culture tube with bleach solution produced the same amount of carbon dioxide as the Yeast+Water+Sugar culture tube.

There were also possible sources of error in this cellular respiration study. When adding pollutants to culture tubes, it is possible that the amount added was close to 3 mL, but not exactly at 3 mL. Each culture tube with pollutants may have differed slightly in rate of cellular respiration because of inaccurate amount of simulated pollutants. To avoid this error in the future, one could use measuring devices other than graduated cylinders to accurately obtain 3 mL of simulated pollutant. Another possible source of error was contamination in the culture tubes. Culture tubes that were not cleaned properly from previous lab groups may have substances present that would affect cellular respiration rates. To improve this experiment in the future, culture tubes would be washed thoroughly in hot water to completely remove any contaminants. A third possible error involved could be incorrect observation of the culture tube. When examining carbon dioxide production, one should observe the liquid surface from the side of the culture tube at eye level and not at an angle.

There were also sources of uncertainty in the dry active yeast experiment. In the case of pollutants, bleach solution did not decrease cellular respiration of yeast while the other pollutants did. The uncertainty is if bleach solution truly does not have any effect on cellular respiration. This uncertainty is present because both isopropyl alcohol and bleach share a common characteristic; they are both cleaning liquids used by humans. Isopropyl alcohol reduces cellular respiration rate to 0 mL/min while bleach has no effect at all. To clear this uncertainty, research could be conducted to better understand the molecular structure of bleach. There is a possibility that the structure of bleach is the reason for no effect on cellular respiration.

Compared to other experiments, the results of this experiment showed great similarity with the others. Results revealed that when sugar is not present, cellular respiration will not take place. When sugar is present, cellular respiration will occur at a much higher rate if pollutants are absent. The six culture tubes with pollutants had significantly lower cellular respiration rates except for the culture tube with bleach solution. Carbohydrates play a vital role in cellular respiration while several pollutants can restrict the process by lowering the rate.

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APPENDIX C: STUDENT LAB REPORT (EXAMPLE #2)

The Effects of Different Pollutants on Algal Growth

Abstract

The purpose of this experiment was to compare the effects of nitrogen, phosphorus and acid rain in both low and high concentrations on algal growth. Both excessive nitrogen and phosphorus lead to algal bloom which will damage aquatic environment and acid rain decreases organisms in water systems. Learning how each pollutant affects algal growth is important for understanding how nitrogen, phosphorus, and acid rain can pollute water systems. It was hypothesized that additional nitrogen and phosphorus would increase algal growth and acid rain would have opposite effects. In the experiment, by comparing each absorbance, the growth of algae was determined. As the concentration of nitrogen increased, the algal growth also increased; as the concentration of phosphorus and acid rain increased, the algal growth decreased. Only the result of phosphorus was opposite to the hypothesis, which leads to future research questions.

Introduction

This experiment evaluated how three substances affected algal growth. In the experiment, nitrogen, phosphorus and acid rain were chosen as pollutants. An overabundance of the essential plant nutrients including nitrogen and phosphorus, can cause a rapid increase in the density of algae in an aquatic system, also known as algal bloom (Tubea et al. 1981). Algal bloom creates severely negative impacts on the environment. For example, it will block vital sunlight from reaching underwater plants that provide food for animals and cause rapid and dramatic die-offs of many aquatic organisms (Science Daily 2012). Because sunlight is a necessary factor that will promote the algal growth, it was controlled in the experiment. Since nitrogen and phosphorus are usually discharged from fertilizers for agricultural purposes or household cleaning products, excessive amounts of these two nutrients in the waterways usually occurs, which heavily pollutes water systems (MPCA 2008). Therefore, due to the close relationship between these two substances and algal growth, it's significant to understand how nitrogen and phosphorus affect growth so that people can better control it.

Acid rain, inversely, is known to diminish the aquatic organisms by lowering the pH of the water and posioning water, thereby killing them (USEPA 2012). Because acid rain can directly precipitate into waterways or indirectly flow into streams, lakes after falling on forests, buildings, and road, it has huge negative impacts on aquatic habitats (USEPA 2012). Therefore, it is necessary to know how acid rain decreases algal growth in order to learn how it diminishes aquatic organisms. Hence, people can minimize its negative influence as much as possible.

The absorbance spectrophotometer at 450nm wavelength was used to indirectly determine algal growth in each test tube. The amount of algae growing under different conditions can be compared by measuring absorbance in that the amount of light absorbed is directly proportional to the concentration of absorbing compounds in that sample (Weber State University n. d). In this experiment, the absorbing compounds are algae. In other words, the more algae produce, the higher the absorbance will be observed.

Since nitrogen and phosphorus were provided as nutrients, as the concentration of these two goes up, algal growth will also increase, so it was expected to see that both high nitrogen and phosphorus test tubes would have higher absorbance than both low nitrogen and phosphorus test tubes. Since acid rain can prevent algal growth by oxidization, the more acid rain in the water, the fewer algae will generate, so it was expected to see that the high acid rain test tube would have a lower absorbance than the low acid rain test tube.

Method

The whole experiment was conducted by six groups in two-week interval. In the first week, each group prepared seven 25mL test tubes which were labeled as control, low nitrogen, high nitrogen, low phosphorus, high phosphorus, low acid rain and high acid rain. Then, 2.5mL green cultivated algae was added into each tube. Next, 12.5mL distilled water without any pollutants was added into the control tube. In each low nitrogen, phosphorus and acid rain test tube, 1.5mL of each pollutant and 11.0mL

distilled water were added. In each high nitrogen, phosphorus and acid rain test tube, 3.0mL of each pollutant and 9.5mL distilled water were added. Then, a wrapped piece of a cotton ball in a small square piece of gauze was inserted into the mouth of each tube as a plug. After all these steps were done, all test tubes were placed under the same plant-growth light.

After two weeks, each group used a spectrophotometer to read the absorbance of each tube so that the difference of algal growth could be compared by comparing its absorbance. The first step was to calibrate and zero the spectrophotometer in order to zero out any light absorbed by anything in the solution other than the compound of interest (Weber State University n. d). To do this, a cuvette was filled 3/4 full with distilled water. Then, the exterior of the cuvette was wiped to make it dry by using tissue wipe. Next, this cuvette was placed into the spectrometer with the set of 450nm wavelength. After done this, the absorbance of distilled water was read from the absorbance scale and then the spectrometer was calibrated to zero again.

The second step was to determine the absorbance of each test tube. The base of control test tube was moved in 10cm circle on the table for approximately 10 seconds in order to be thoroughly mixed. Then, the contents were poured into a clean cuvette until 3/4 full. Next, after the exterior of this cuvette being wiped, it was put into the spectrometer with the set of 450nm wavelength, same as the calibration. Afterwards, the absorbance of the control test tube was recorded in the table. Subsequently, the contents were poured back into the test tube and the cuvette was rinsed with distilled water for preparing next test. The rest of test tubes were tested by following the step 2. After all

test tubes been tested, the data of each group was collected and then the mean absorbance of each condition was calculated.

Results

According to the mean absorbance of each test tube, the most algal growth occurred in the low phosphorus test tube; the least algal growth occurred in the high acid rain test tube. Compared to the control, both nitrogen and phosphorus increased the algal growth, while acid rain decreased the algal growth. Comparing both nitrogen test tubes, the high concentration test tube had more algae than the low concentration tube did. Comparing both phosphorus test tubes, the low concentration tube had more algae than the high concentration tube did. Comparing both acid rain test tubes, the high concentration test tube had slightly fewer algae than the low concentration tube did. Comparing each group's data, three of the six groups had higher absorbance in the high concentration of phosphorus test tube; the results of the other three groups were opposite. Comparing each group's data in both low and high acid rain conditions, group #3 demonstrated much higher absorbance than any other group. Comparing both nitrogen and both phosphorus test tubes, data from each group were various. All data can be seen in the Table 1.

Table 1 Absorbance (at 450nm) of control versus pollutant treatment by concentration and lab group

	Absorbance						
Lab Group	Control	Low Nitrogen	High Nitrogen	Low Phosphorous	High Phosphorous	Low Acid Rain	High Acid Rain
1	0.017	0.066	0.096	0.24	0.065	0.005	0.004
2	0.128	0.183	0.325	0.574	0.195	0.004	0.011
3	0.406	0.5	0.47	0.428	0.456	0.302	0.295
4	0.037	0.215	0.38	0.081	0.165	0.002	0.002
5	0.015	0.079	0.03	0.033	0.025	0.005	0.003
6	0.08	0.1	0.55	0.56	0.72	0.02	0.02
Mean	0.1005	0.1734	0.2168	0.226	0.151	0.053	0.0525

Discussion

The expected result for nitrogen of this experiment was that the absorbance of the high nitrogen test tube would be higher than the low nitrogen test tube. The results demonstrated such effects. As the concentration of nitrogen increased, more algae were generated. The presence of this trend represents a close and positive relationship between nitrogen and algal growth. The increase of nitrogen would trigger the algal growth. Therefore, people should strictly control the use of nitrogen products. For example,

people should regularly treat pollutants before disposing of fertilizers or household cleaning products which contain nitrogen.

In terms of the two phosphorus test tubes, the high one was expected to have higher absorbance than the low one because algal growth was expected to increase as the concentration of phosphorus increases. On the contrary, the results didn't support this hypothesis. The possible reason of these unexpected results may be that, because algae tend to grow very quickly under high phosphorous availability and each alga is short-lived, these algae start to decay. So some groups' high phosphorous test tubes had less algal growth. In order to make the effects of phosphorus on algal growth clearer, further investigations can test how different lengths of exposure to phosphorus affects the algal growth. Another reason for this unexpected result was that the wrong way was used for spectrophotometer, since it was the first time for students to use it. Inappropriate operation would lead to wrong results. For instance, group #3 which had relatively higher absorbance in both acid rain tubes may have set the wrong wavelength of spectrophotometer instead of 450nm, thereby resulting the absorbance being much higher than other groups.

The expected result of two acid rain test tubes was that the high acid rain tube had lower absorbance than the low acid rain tube because as the concentration of acid rain increases, the algae would decrease. The results showed such effects and supported that the acidic environment was harmful for the algal growth. The result that the control test tube had higher absorbance than both acid rain test tubes also supported that acid rain would restrain the algal growth. This conclusion could be applied in the control or

manage the algal bloom. People can use a proper amount of relatively harmless acidic products to decrease the excessive amounts of algae.

In conclusion, this experiment tested how different concentration of three kinds of pollutants: nitrogen, phosphorus and acid rain affected algal growth. It was shown that as the concentration of nitrogen increased, the algal growth also increased; as the concentration of phosphorus and acid rain increased, the algal growth decreased. The hypothesis that the more phosphorus is in the water, the more algae would produce was not supported in this experiment. Data showed that adding nitrogen and phosphorus indeed promoted the algal growth, while the addition of acid rain decreased the amount of algae. As a result, the control of nitrogen and phosphorus should be considered and the efforts to decrease the precipitation of acid rain should be reinforced.

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APPENDIX D: SURVEY CONSENT FORM FOR STUDENTS

STUDENT SURVEY (ELECTRONIC CONSENT)

Please read the following before proceeding with this survey.

RESEARCH PROCEDURES

Principal Investigator Dr. Paul M. Rogers and co-investigator Anthony Kalaskas are conducting research surveys on the teaching and learning of the scientific lab report. Surveys will be conducted with undergraduate science majors and instructors/TAs who teach biology and/or chemistry lab courses. Such action will be taken in order to ascertain the attitudes, beliefs, and values that are engendered when instructors and students participate in the teaching and learning of the lab report. Research findings may potentially inform teaching and learning strategies designed to help undergraduate science majors and lab instructors/TAs here at George Mason University.

The survey questions will be about:

- Teaching of the lab report
- Learning of the lab report
- Writing of the lab report
- Evaluation of the lab report
- Attitudes, beliefs, and values about the lab report

The procedure involves completing an online survey that will take approximately 5 to 10 minutes. However, there is no time limit and you may therefore take as much time as you need to complete the questions.

RISKS

There are no foreseeable risks for participating in this research.

BENEFITS

There are no direct benefits for participating. However, your participation may help contribute in providing recommendations regarding the teaching and learning of the science lab report for undergraduate science majors.

CONFIDENTIALITY

Your responses will be confidential and we will not collect any identifying information, such as your name, e-mail address or IP address.

We will do our best to keep your information confidential. All data is stored in a password protected electronic format. To help protect your confidentiality, the surveys will not contain information that will personally identify you. The results of this study will be used for scholarly purposes only.

PARTICIPATION

Your participation in this research study is voluntary. You may choose not to participate. If you decide to participate in this research survey, you may withdraw at any time. You may discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled.

CONTACT

If you have any questions about this research study, please e-mail:

- Principal Investigator Dr. Paul M. Rogers (progers2@gmu.edu)
- Co-Investigator Anthony Kalaskas (akalaska@masonlive.gmu.edu)

You may also contact the George Mason University Office of Research Subject Protections at 703-993-4121 if you have questions regarding your rights as a participant in this research.

This research has been reviewed according to George Mason University IRB procedures for research involving human subjects.

1. ELECTRONIC CONSENT (Question #1 is answering the consent question)

Clicking on the "AGREE" button below indicates that

- You have read the above information
- You voluntarily agree to participate

If you choose "AGREE", you will proceed forward to the survey questions.

If you do not wish to participate in this research study, please decline participation by clicking on the "DISAGREE" button.

If you choose “DISAGREE”, you will be re-directed to the George Mason University homepage.

Please select your choice below.
(Multiple choice, choose only one).

- AGREE
- DISAGREE

APPENDIX E: SURVEY CONSENT FORM FOR INSTRUCTORS

INSTRUCTOR/TA SURVEY (ELECTRONIC CONSENT)

Please read the following before proceeding with this survey.

RESEARCH PROCEDURES

Principal Investigator Dr. Paul M. Rogers and co-investigator Anthony Kalaskas are conducting research surveys on the teaching and learning of the scientific lab report. Surveys will be conducted with undergraduate science majors and instructors/TAs who teach biology and/or chemistry lab courses. Such action will be taken in order to ascertain the attitudes, beliefs, and values that are engendered when instructors and students participate in the teaching and learning of the lab report. Research findings may potentially inform teaching and learning strategies designed to help undergraduate science majors and lab instructors/TAs here at George Mason University.

The survey questions will be about:

- Teaching of the lab report
- Learning of the lab report
- Writing of the lab report
- Evaluation of the lab report
- Attitudes, beliefs, and values about the lab report

The procedure involves completing an online survey that will take approximately 5 to 10 minutes. However, there is no time limit and you may therefore take as much time as you need to complete the questions.

RISKS

There are no foreseeable risks for participating in this research.

BENEFITS

There are no direct benefits for participating. However, your participation may help contribute in providing recommendations regarding the teaching and learning of the science lab report for undergraduate science majors.

CONFIDENTIALITY

Your responses will be confidential and we will not collect any identifying information, such as your name, e-mail address or IP address.

We will do our best to keep your information confidential. All data is stored in a password protected electronic format. To help protect your confidentiality, the surveys will not contain information that will personally identify you. The results of this study will be used for scholarly purposes only.

PARTICIPATION

Your participation in this research study is voluntary. You may choose not to participate. If you decide to participate in this research survey, you may withdraw at any time. You may discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled.

CONTACT

If you have any questions about this research study, please e-mail:

- Principal Investigator Dr. Paul M. Rogers (progers2@gmu.edu)
- Co-Investigator Anthony Kalaskas (akalaska@masonlive.gmu.edu)

You may also contact the George Mason University Office of Research Subject Protections at 703-993-4121 if you have questions regarding your rights as a participant in this research.

This research has been reviewed according to George Mason University IRB procedures for research involving human subjects.

1. ELECTRONIC CONSENT (Question #1 is answering the consent question)

Clicking on the "AGREE" button below indicates that

- You have read the above information
- You voluntarily agree to participate

If you choose "AGREE", you will proceed forward to the survey questions.

If you do not wish to participate in this research study, please decline participation by clicking on the "DISAGREE" button.

If you choose “DISAGREE”, you will be re-directed to the George Mason University homepage.

Please select your choice below.
(Multiple choice, choose only one).

- AGREE
- DISAGREE

APPENDIX F: INTERVIEW CONSENT FORM FOR STUDENTS

STUDENT CONSENT FORM

Understanding the Scientific Lab Report at the College Level

RESEARCH PROCEDURES
Principal Investigator Dr. Paul Rogers and co-investigator Anthony Kalaskas are conducting research interviews on the teaching and learning of the scientific lab report. Interviews will be conducted with undergraduate science majors and instructors/TAs who teach biology and/or chemistry lab courses. Such action will be taken in order to ascertain the attitudes, beliefs, and values that are engendered when instructors and students participate in the teaching and learning of the lab report. Research findings may potentially inform teaching and learning strategies designed to help undergraduate science majors and lab instructors/TAs here at Mason. Interviews will be transcribed, and portions of the interviews may be used in publications and conference presentations.

The research team will be asking you questions in the following areas:

- Teaching of the lab report
- Learning of the lab report
- Writing of the lab report
- Evaluation of the lab report
- Attitudes, beliefs, and values about the lab report

If you agree to participate in this interview process, you will be meeting with co-investigator Anthony Kalaskas to discuss these questions. The interview will take between 30 and 45 minutes. The interview will be audio taped and transcribed. You will be identified by a pseudonym and by discipline.

RISKS
There are no foreseeable risks for participating in this research.

BENEFITS
There are no direct benefits for participating. However, your participation may help contribute in providing recommendations regarding the teaching and learning of the science lab report for undergraduate science majors.

CONFIDENTIALITY
Interviews will be recorded via a digital audio recorder. The digital audio recorder will be kept in a secure lock box in the co-investigator's office. Audio recordings of interviews will be transcribed onto a word document and stored on a password-protected computer. Upon completion of the study, all audio recordings and transcriptions of interview data will be eliminated. All audio recordings and audio files will be erased, and all word documents containing transcribed interview data will be deleted and shredded.

All data/findings presented at conferences, in published material, and in other media will be identified by a pseudonym.

PARTICIPATION
You will receive $15 for your participation in this study. Participation is completely voluntary. Refusal to participate will not involve penalties or loss of benefits to which you are otherwise entitled. You may discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled.

CONTACT
If you have any questions about the research project, you may contact principal investigator Dr. Paul M. Rogers at HYPERLINK "mailto:progers2@gmu.edu" progers2@gmu.edu, and co-investigator Anthony Kalaskas at HYPERLINK "mailto:akalaska@masonlive.gmu.edu" akalaska@masonlive.gmu.edu. You may also contact the George Mason University Office of Research Subject Protections at 703-993-4121 if you have questions regarding your rights as a participant in this research. This research has been reviewed according to George Mason University procedures governing your participation in this research.

CONSENT
Please circle yes or no after each item and sign below:

I have read this form and agree to participate in this research study YES/NO
I agree to have transcribed excerpts from my interview used YES/NO
I agree to have audio excerpts from my recorded interview used YES/NO

Print Name:_____

Signature:_____

Date:_____

Please return to Dr. Paul Rogers, MSN 3E4.

APPENDIX G: INTERVIEW CONSENT FORM FOR INSTRUCTORS

INSTRUCTOR/TEACHING ASSISTANT CONSENT FORM

Understanding the Scientific Lab Report at the College Level

RESEARCH PROCEDURES
Principal Investigator Dr. Paul Rogers and co-investigator Anthony Kalaskas are conducting research interviews on the teaching and learning of the scientific lab report. Interviews will be conducted with undergraduate science majors and instructors/TAs who teach biology and/or chemistry lab courses. Such action will be taken in order to ascertain the attitudes, beliefs, and values that are engendered when instructors and students participate in the teaching and learning of the lab report. Research findings may potentially inform teaching and learning strategies designed to help undergraduate science majors and lab instructors/TAs here at Mason. Interviews will be transcribed, and portions of the interviews may be used in publications and conference presentations.

The research team will be asking you questions in the following areas:

- Teaching of the lab report
- Learning of the lab report
- Writing of the lab report
- Evaluation of the lab report
- Attitudes, beliefs, and values about the lab report

If you agree to participate in this interview process, you will be meeting with co-investigator Anthony Kalaskas to discuss these questions. The interview will take about 30 minutes. The interview will be audio taped and transcribed. You will be identified by a pseudonym and by discipline.

RISKS
There are no foreseeable risks for participating in this research.

BENEFITS

There are no direct benefits for participating. However, your participation may help contribute in providing recommendations regarding the teaching and learning of the science lab report for undergraduate science majors.

CONFIDENTIALITY
Interviews will be recorded via a digital audio recorder. The digital audio recorder will be kept in a secure lock box in the co-investigator's office. Audio recordings of interviews will be transcribed onto a word document and stored on a password-protected computer. Upon completion of the study, all audio recordings and transcriptions of interview data will be eliminated. All audio recordings and audio files will be erased, and all word documents containing transcribed interview data will be deleted and shredded.

All data/findings presented at conferences, in published material, and in other media will be identified by a pseudonym.

PARTICIPATION
Participation is completely voluntary. Refusal to participate will not involve penalties or loss of benefits to which you are otherwise entitled. You may discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled.

CONTACT
If you have any questions about the research project, you may contact principal investigator Dr. Paul M. Rogers at HYPERLINK "mailto:progers2@gmu.edu" progers2@gmu.edu, and co-investigator Anthony Kalaskas at HYPERLINK "mailto:akalaska@masonlive.gmu.edu" akalaska@masonlive.gmu.edu. You may also contact the George Mason University Office of Research Subject Protections at 703-993-4121 if you have questions regarding your rights as a participant in this research. This research has been reviewed according to George Mason University procedures governing your participation in this research.

CONSENT
Please circle yes or no after each item and sign below:

I have read this form and agree to participate in this research study YES/NO
I agree to have transcribed excerpts from my interview used YES/NO
I agree to have audio excerpts from my recorded interview used YES/NO

Print Name:_____

Signature:_____

Date:_____

Please return to Dr. Paul Rogers, MSN 3E4.

APPENDIX H: SURVEY INSTRUMENT FOR STUDENTS

Student Survey – Science Lab Report Writing

We recognize that there are many challenges that undergraduate science majors face when writing lab reports. This survey is intended to help us better understand the challenges these students encounter when going through the writing process.

For the purposes of my study, I am focusing on the following:

- Teaching of the lab report
- Learning of the lab report
- Writing of the lab report
- Evaluation of the lab report
- Attitudes, beliefs, and values about the lab report

Survey Instrument

Begin Page #1

Directions: The following survey contains a total of 15 questions (beginning at question #2 and ending at question #16), and is divided into 4 parts: Demographics, The Laboratory Report Itself, Instruction, and Comments/Reflection.

The total time it takes to complete this survey should be approximately 5 to 10 minutes. There is no time limit, though, and you may therefore take as much time as you need to answer the questions. There are no right or wrong answers.

Part I. Demographics

2. What is your undergraduate level?
   (Multiple choice, choose only one)
   - Freshman
   - Sophomore
   - Junior
   - Senior
   - Prefer not to respond

- Other (please specify)

3. What is your major(s)? Check all that apply.
    - Biology
    - Chemistry
    - Prefer not to respond
    - Other (please specify)

End Page #1

Begin Page #2

Part II. The Laboratory Report Itself

For questions #4 to #6, please respond to what you think about the following statements. There are no right or wrong answers.

4. I like writing science lab reports. (5 point Likert scale, choose only one)
    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree
    - N/A

5. I think the science lab report is an important part of college laboratory courses. (5 point Likert scale, choose only one)
    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree
    - N/A

6. I think learning how to write lab reports is valuable because they may help me in the setting of workplace laboratories. (5 point Likert scale, choose only one)
    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree
    - N/A

End Page #2

Begin Page #3

7. What are the most challenging aspects of doing a lab report? Check all that apply.
    - Analysis of Data
    - Calculations
    - Organization
    - Writing
    - None of the Above
    - Prefer not to respond
    - Other (please specify)

8. When a lab report is evaluated and graded, what do you think are the most important elements that should be looked at? Check all that apply.
    - Formatting
    - Organization
    - Accuracy of Data
    - Discussion of Results
    - Grammar
    - Writing Style
    - Writing Mechanics
    - Figures, Tables, Graphs
    - None of the Above
    - Prefer not to respond
    - Other (please specify)

End Page #3

Begin Page #4

Part III. Instruction

For questions #9 to #12, please respond to what you think about the following statements. There are no right or wrong answers.

9. I feel that high school prepared me for the lab report writing I do in college. (5 point Likert scale, choose only one)
    - Strongly Disagree
    - Disagree
    - Neutral

- Agree
- Strongly Agree
- N/A

10. I felt prepared to write lab reports when I took my first lab course in college. (5 point Likert scale, choose only one)
    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree
    - N/A

11. In general, I believe that the instruction I have received about lab report writing during my lab course sessions has been effective and helpful. (5 point Likert scale, choose only one)
    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree
    - N/A

12. I feel that my lab instructor/TA has a responsibility to help me with my writing. (5 point Likert scale, choose only one)
    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree
    - N/A

End Page #4

Begin Page #5

13. Which of the following resources have you ever consulted with when writing lab reports? Check all that apply.
    - Meeting with instructor/TA during office hours
    - Written comments and feedback on graded lab reports
    - Student writing center
    - Online resources

- Advice from other students
- None of the above
- Prefer not to respond
- Other (please specify)

14. Of the resources you have used, which do you feel was the most effective and helpful when writing lab reports? Why?
    If you prefer not to respond, please type "N/A".
    (Comment box for free-response)

15. Which of the following do you think would help your writing of lab reports the most? Check all that apply.
    - Extended office hours of instructor/TA
    - Lesson on lab report writing given by the instructor/TA
    - A detailed template of a sample lab report
    - A list of possible online resources about lab report writing
    - A list of grading guidelines/rubric
    - None of the above
    - Prefer not to respond
    - Other (please specify)

End Page #5

Begin Page #6

Part IV. Comments/Reflection

16. Please add any final comments or thoughts you may have.
    If there are any questions that were not asked that you feel should have been asked, please indicate those as well.
    (Comment box for free-response)

End Page #6

APPENDIX I: SURVEY INSTRUMENT FOR INSTRUCTORS

Instructor/TA Survey – Science Lab Report Writing

We recognize that there are many challenges that undergraduate science majors face when writing lab reports. This survey is intended to help us better understand the perspective of instructors/TAs who instruct these undergraduate science majors who write lab reports.

For the purposes of my study, I am focusing on the following:

- Teaching of the lab report
- Learning of the lab report
- Writing of the lab report
- Evaluation of the lab report
- Attitudes, beliefs, and values about the lab report

Survey Instrument

Begin Page #1

Directions: The following survey contains a total of 14 questions (beginning at question #2 and ending at question #15), and is divided into 5 parts: Demographics, The Laboratory Report Itself, Evaluation, Instruction, and Comments/Reflection.

The total time it takes to complete this survey should be approximately 5 to 10 minutes. There is no time limit, though, and you may therefore take as much time as you need to answer the questions. There are no right or wrong answers.

Part I. Demographics

2. What is your discipline? Check all that apply.
    - Biology
    - Chemistry
    - Prefer not to respond
    - Other (please specify)

End page #1

Begin page #2

Part II. The Lab Report Itself

For questions #3 and #4, please respond to what you think about the following statements. There are no right or wrong answers.

3. I feel that teaching students how to write a lab report is an important part of college lab courses. (5 point Likert scale, choose only one)
    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree
    - N/A

4. I think that the skills required to write a good lab report are valuable because they carry over into the setting of workplace laboratories. (5 point Likert scale, choose only one)
    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree
    - N/A

End page #2

Begin page #3

5. What do you think the purpose of the lab report is?
   If you prefer not to respond, please type "N/A".
   (Comment box for free-response)

6. Please list the features of a satisfactory lab report.
   If you prefer not to respond, please type "N/A".
   (Comment box for free-response)

7. Please list the features of an unsatisfactory lab report.
   If you prefer not to respond, please type "N/A".
   (Comment box for free-response)

End page #3

Begin page #4

Part III. Evaluation

8. Do you use a rubric to evaluate and grade student lab reports?
   (Multiple choice, choose only one)
   - Yes
   - No
   - Prefer not to respond

9. Please list the criteria that you use to evaluate student lab reports, and the proportions to which they form the grade. (e.g. Introduction = 10%, Grammar = 5%, Graphs/Tables = 15%, etc.)
   If you prefer not to respond, please type "N/A".
   (Comment box for free-response)

10. How much weight and/or focus do you place on the actual student writing itself?
    (Multiple choice, choose only one)
    - A great deal
    - A lot
    - A moderate amount
    - A little
    - Not at all
    - Prefer not to respond

End page #4

Begin page #5

11. When you evaluate lab reports, where do you notice students struggle the most?
    Check all that apply.
    - Formatting
    - Organization
    - Accuracy of Data
    - Discussion of Results
    - Grammar
    - Writing Style
    - Writing Mechanics
    - Figures, Tables, Graphs
    - None of the Above

- Prefer not to respond
- Other (please specify)

12. How prepared do you think your students are to produce the level of writing required for undergraduate science lab reports?
    (Multiple choice, choose only one)
    - Extremely prepared
    - Very prepared
    - Moderately prepared
    - Slightly prepared
    - Not at all prepared
    - Prefer not to respond

End page #5

Begin page #6

Part IV. Instruction

13. Have you found it necessary to give "lessons" on writing lab reports to your students? If yes, explain why. If no, explain why not.
    If you prefer not to respond, please type "N/A".
    (Comment box for free-response)

14. What are one or two pieces of writing advice, if any, that you find yourself giving most often to students writing science lab reports?
    If you prefer not to respond, please type "N/A".
    (Comment box for free-response)

End page #6

Begin page #7

Part V. Comments/Reflection

15. Please add any final comments or thoughts you may have. If there are any questions that were not asked that you feel should have been asked, please indicate those as well.
    (Comment box for free-response)

End page #7

APPENDIX J: INTERVIEW PROTOCOL FOR STUDENTS

Student Interview Protocol

Introductions and thank you for participating

My name is……..

Sponsors
The Office of Graduate Studies and I are arranging these meetings. We're doing these discussions with undergraduate biology and/or chemistry majors because we want to hear directly from you about your experiences in writing science lab reports.

Confidentiality….. We are only interested in finding out about your experiences so that we can develop successful strategies for undergraduates writing science lab reports.

Master's Thesis
I will be writing a master's thesis based on the results of this study.
Offer to send a copy of the thesis.

Digital Audio Recording – Verbal consent for digital audio recording. Upon consenting, tell the student that he/she will be identified by a pseudonym. In this case, "Student #1", "Student #2", "Student #3", etc.

Content of the Interview
We'll spend some of our time talking about the challenges undergraduate biology and/or chemistry majors face when writing lab reports. We'll also discuss the effect that instructors/TAs have on the teaching and learning of the lab report.

Define what I mean by science lab report writing:
The lab report writing that occurs in undergraduate science laboratory courses.

- Teaching of the lab report
- Learning of the lab report

- Writing of the lab report
- Evaluation of the lab report
- Attitudes, beliefs, and values about the lab report

Part I. Demographic Information

What is your undergraduate level (e.g. freshman, sophomore, junior, senior, other)?

What is your major(s)? What is your minor(s), if any?

Part II. The Laboratory Report Itself

1. Tell me about your experiences writing science lab reports.

2. Do you remember your first experience writing a science lab report in college?
   - If yes, describe what that was like.

3. Based on your experiences, tell me what you like about writing lab reports.

4. Based on your experiences, tell me what you don't like about writing lab reports.

5. What are the most challenging aspects of writing a lab report?
   - Tell me why you think that is the case.

6. Why do you think the lab report is important in college-level lab courses?

7. How much value do you think the lab report carries in the setting of workplace laboratories?
   - Why do you think that is the case?

8. How do you think the lab report should be formatted and/or structured?

9. What do you think the features of a satisfactory lab report are?

10. What do you think the features of an unsatisfactory lab report are?

Part III. Instruction

11. How much did high school help to prepare you for the level of lab report writing required in college?

- Why do you think that is the case?

12. Did you feel prepared to write lab reports when you took your first science lab course?
    - Tell me why you feel that way.

13. Tell me about the instruction on lab report writing that you received in your laboratory courses, especially in biology and/or chemistry.

14. Did you consult any resources in order to write your lab reports?
    - If yes, describe and tell me about them.

15. What resource did you find most helpful when you wrote your lab reports?
    - Tell me why you think that was the case.

16. What would you like to know from your lab instructor before writing a lab report?

17. To what degree do you think your lab instructor/TA feels responsible to help you with your writing? How often do they proofread or edit your work?

18. Did your lab instructor/TA ever suggest that you seek outside help (e.g. writing center, how-to guides, websites, etc.)?

19. What are one or two pieces of writing advice you have heard most frequently regarding science lab report writing?

20. How often, if ever, has your lab instructor/TA drawn on his/her own experiences writing lab reports in giving you advice?
    - If yes, what did he/she say?

21. What kinds of writing support do you think should be made available for undergraduate science majors writing lab reports?

Part IV. Final Questions – Comments/Reflection

22. Do you have any final comments or thoughts you would like to add that you may have thought of during the interview?
    - If yes, tell me what they are.

23. Are there any questions that you think I should have asked during the interview that I didn't ask?
    - If yes, tell me what they are.

APPENDIX K: INTERVIEW PROTOCOL FOR INSTRUCTORS

Instructor/TA Interview Protocol

Introductions and thank you for participating

My name is……..

Sponsors
The Office of Graduate Studies and I are arranging these meetings. We're doing these discussions with faculty in biology and/or chemistry because we want to hear directly from lab instructors/TAs about their experiences in instructing undergraduate science majors writing science lab reports.

Confidentiality….. We are only interested in finding out about your experiences so that we can develop successful strategies for undergraduates writing science lab reports.

Master's Thesis
I will be writing a Master's thesis based on the results of this study.
Offer to send a copy of the thesis.

Digital Audio Recording – Verbal consent for digital audio recording. Upon consenting, tell the instructor/TA that he/she will be identified by a pseudonym. In this case, "Instructor #1", "Instructor #2", "Instructor #3", etc.

Content of the Interview
We'll spend some of our time talking about the significance of the lab report. We'll also discuss the criteria for evaluating lab reports, as well as the work of instructing students when they write lab reports.

Define what I mean by science lab report writing:
The lab report writing that occurs in undergraduate science laboratory courses.

- Teaching of the lab report

- Learning of the lab report
- Writing of the lab report
- Evaluation of the lab report
- Attitudes, beliefs, and values about the lab report

Part I. Demographic Information

What is your discipline?

What lab courses have you taught in your career?

Part II. The Laboratory Report Itself

1. What do you think the purpose of the lab report is?

2. Why do you think the lab report is important in college-level lab courses?

3. How much value do you think the lab report carries in the setting of workplace laboratories?
   - Why do you think that is the case?

Do you give any pre-lab assignments?

4. How do you think the lab report should be formatted and/or structured? (e.g. the section names and what order they should be listed)

What do you think is the most important section in a lab report? (Why?)

What do you think is the least important section in a lab report? (Why?)

5. What do you think the features of a satisfactory lab report are?

6. What do you think the features of an unsatisfactory lab report are?

7. How standard are these features across science disciplines?

Part III. Evaluation

8. Do you use a rubric to grade lab reports?
   - If yes, describe what criteria are on it and how much each counts towards the

total grade.
- If no, what method do you use to grade? Describe it to me.

9. What elements of writing do you focus on the most when evaluating lab reports?
   - Tell me why that is so.

10. Based on your experience, what elements of lab report writing do you believe students find the most challenging?

11. When you evaluate lab reports, where do you notice students struggle the most?
    - How do you account for these struggles?

Part IV. Instruction

12. How prepared do you think your students are to produce the level of writing required for an undergraduate lab course?
    - Why do you think that is the case?

13. Do you provide any resources to your students about writing lab reports?
    - If yes, describe these resources.

14. Have you found it necessary to give "lessons" on writing lab reports to your students?
    - If yes, describe the lesson(s) you give.

15. What are one or two pieces of writing advice you find yourself giving most often to students writing lab reports?

Part V. Final Questions – Comments/Reflection

16. Do you have any final comments or thoughts you would like to add that you may have thought of during the interview?
    - If yes, tell me what they are.

17. Are there any questions that you think I should have asked during the interview that I didn't ask?
    - If yes, tell me what they are.

APPENDIX L: SURVEY RECRUITMENT E-MAIL FOR STUDENTS

Dear Undergraduate Science Major:

My name is Anthony Kalaskas and I am a graduate student in the Department of English here at George Mason University. I am writing to invite you to participate in a research study for my Master's thesis that I am conducting, which focuses on the experience of writing a scientific lab report.

In order to participate, you simply have to do an online survey, which takes approximately 5 to 10 minutes to complete. You may participate if you are either a biology and/or chemistry major, and have completed at least one lab report in a lab course taught at Mason.

The link to participate in the online survey:

[SURVEY LINK]

There are no risks to this study, and no benefits beyond providing information that will potentially inform teaching and learning strategies designed to help undergraduate science majors and lab instructors/TAs here at Mason. All information will be kept confidential, and pseudonyms will be used in all research reporting.

If you have any questions about the research study for my Master's thesis, please contact me at akalaska@masonlive.gmu.edu

Thank you for your consideration,

Anthony Kalaskas

APPENDIX M: SURVEY RECRUITMENT E-MAIL FOR INSTRUCTORS

Dear Instructor/TA _____:

My name is Anthony Kalaskas and I am a graduate student in the Department of English here at George Mason University. I am writing to invite you to participate in a research study for my Master's thesis that I am conducting, which focuses on the experience of writing a scientific lab report. The Office of Graduate Studies is sponsoring my study.

In order to participate, you simply have to do an online survey, which takes approximately 5 to 10 minutes to complete. You may participate if you have or are actively teaching a science lab course in biology and/or chemistry.

The link to participate in the online survey:

[SURVEY LINK]

There are no risks to this study, and no benefits beyond providing information that will potentially inform teaching and learning strategies designed to help undergraduate science majors and lab instructors/TAs here at Mason. All information will be kept confidential, and pseudonyms will be used in all research reporting.

If you have any questions about the research study for my Master's thesis, please contact me at akalaska@masonlive.gmu.edu

Thank you for your consideration,

Anthony Kalaskas

APPENDIX N: INTERVIEW RECRUITMENT E-MAIL FOR STUDENTS

Dear Undergraduate Science Major:

My name is Anthony Kalaskas and I am a graduate student in the Department of English here at George Mason University. I am writing to invite you to participate in a research study for my Master's thesis that I am conducting, which focuses on the experience of writing a scientific lab report.

You may participate if you are either a biology and/or chemistry major, and have completed at least one lab report in a lab course taught at Mason.

As a participant, you will be asked to take part in an individual interview. Interviews will range from 30 minutes to 45 minutes. You will receive $15.00 for your participation in the interview.

There are no risks to this study, and no benefits beyond providing information that will potentially inform teaching and learning strategies designed to help undergraduate science majors here at Mason. All information will be kept confidential, and pseudonyms will be used in all research reporting.

If you would like to participate in the research study for my Master's thesis or have any questions about my study, please contact me at akalaska@masonlive.gmu.edu

Thank you for your consideration,

Anthony Kalaskas

APPENDIX O: INTERVIEW RECRUITMENT E-MAIL FOR INSTRUCTORS

Dear Instructor/TA _____:

My name is Anthony Kalaskas and I am a graduate student in the Department of English here at George Mason University. I am writing to invite you to participate in a research study for my Master's thesis that I am conducting, which focuses on the experience of writing a scientific lab report. The Office of Graduate Studies is sponsoring my study.

As a participant, you will be asked to take part in an individual interview that focuses on the teaching and learning of lab report writing. Interviews will take 30 minutes. You may participate if you have or are actively teaching a science lab course in biology and/or chemistry.

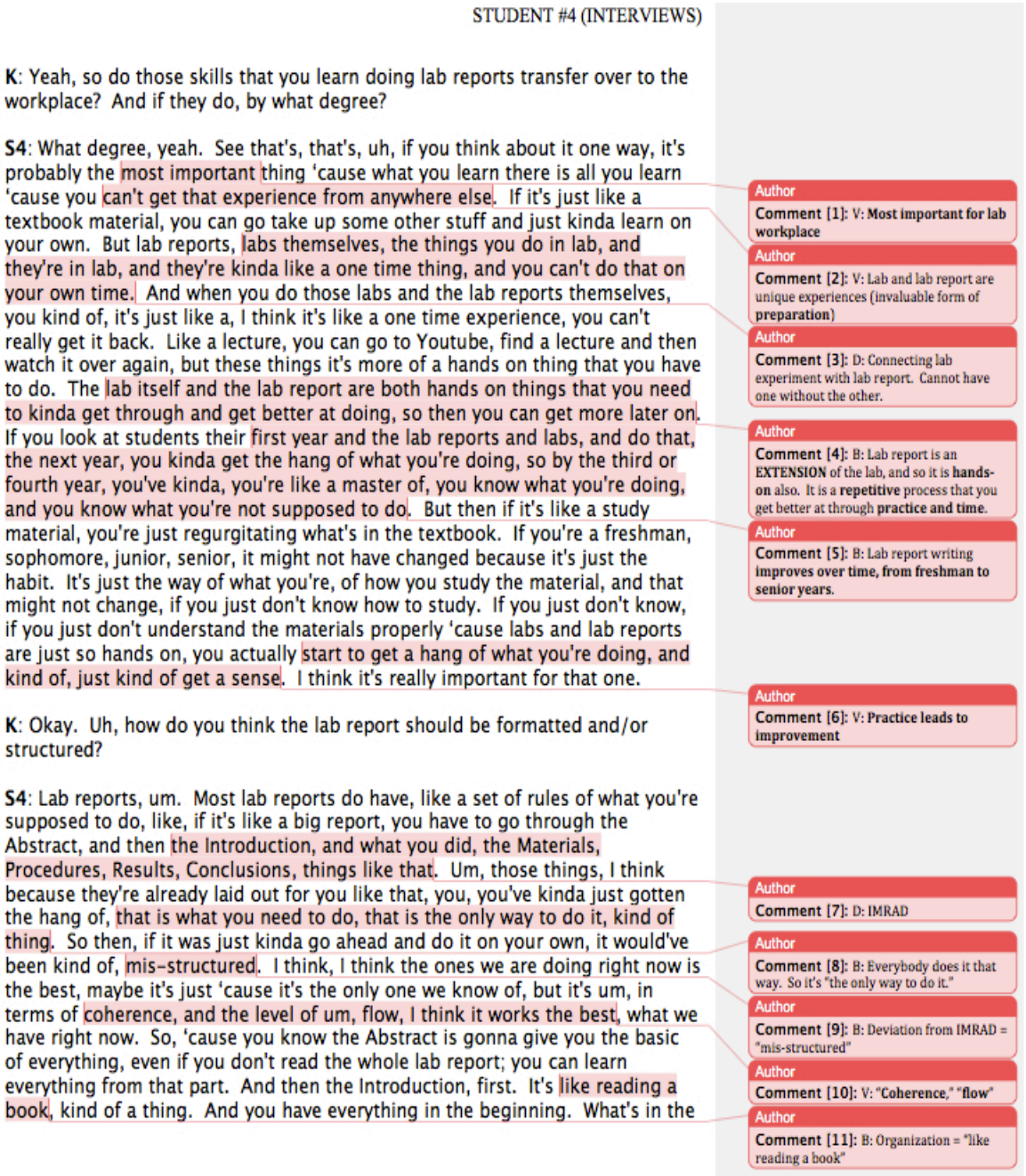
There are no risks to this study, and no benefits beyond providing information that will potentially inform teaching and learning strategies designed to help undergraduate science majors and lab instructors/TAs here at Mason. All information will be kept confidential, and pseudonyms will be used in all research reporting.

If you would like to participate in the research study for my Master's thesis or have any questions about my study, please contact me at akalaska@masonlive.gmu.edu

Thank you for your consideration,

Anthony Kalaskas

APPENDIX P: CODING EXCERPT OF STUDENT INTERVIEW



STUDENT #4 (INTERVIEWS)

K: Yeah, so do those skills that you learn doing lab reports transfer over to the workplace? And if they do, by what degree?

S4: What degree, yeah. See that's, that's, uh, if you think about it one way, it's probably the most important thing 'cause what you learn there is all you learn 'cause you can't get that experience from anywhere else. If it's just like a textbook material, you can go take up some other stuff and just kinda learn on your own. But lab reports, labs themselves, the things you do in lab, and they're in lab, and they're kinda like a one time thing, and you can't do that on your own time. And when you do those labs and the lab reports themselves, you kind of, it's just like a, I think it's like a one time experience, you can't really get it back. Like a lecture, you can go to Youtube, find a lecture and then watch it over again, but these things it's more of a hands on thing that you have to do. The lab itself and the lab report are both hands on things that you need to kinda get through and get better at doing, so then you can get more later on. If you look at students their first year and the lab reports and labs, and do that, the next year, you kinda get the hang of what you're doing, so by the third or fourth year, you've kinda, you're like a master of, you know what you're doing, and you know what you're not supposed to do. But then if it's like a study material, you're just regurgitating what's in the textbook. If you're a freshman, sophomore, junior, senior, it might not have changed because it's just the habit. It's just the way of what you're, of how you study the material, and that might not change, if you just don't know how to study. If you just don't know, if you just don't understand the materials properly 'cause labs and lab reports are just so hands on, you actually start to get a hang of what you're doing, and kind of, just kind of get a sense. I think it's really important for that one.

K: Okay. Uh, how do you think the lab report should be formatted and/or structured?

S4: Lab reports, um. Most lab reports do have, like a set of rules of what you're supposed to do, like, if it's like a big report, you have to go through the Abstract, and then the Introduction, and what you did, the Materials, Procedures, Results, Conclusions, things like that. Um, those things, I think because they're already laid out for you like that, you, you've kinda just gotten the hang of, that is what you need to do, that is the only way to do it, kind of thing. So then, if it was just kinda go ahead and do it on your own, it would've been kind of, mis-structured. I think, I think the ones we are doing right now is the best, maybe it's just 'cause it's the only one we know of, but it's um, in terms of coherence, and the level of um, flow, I think it works the best, what we have right now. So, 'cause you know the Abstract is gonna give you the basic of everything, even if you don't read the whole lab report; you can learn everything from that part. And then the Introduction, first. It's like reading a book, kind of a thing. And you have everything in the beginning. What's in the

Author
Comment [1]: V: **Most important for lab workplace**

Author
Comment [2]: V: Lab and lab report are unique experiences (invaluable form of **preparation**)

Author
Comment [3]: D: Connecting lab experiment with lab report. Cannot have one without the other.

Author
Comment [4]: B: Lab report is an **EXTENSION** of the lab, and so it is **hands-on** also. It is a **repetitive** process that you get better at through **practice and time**.

Author
Comment [5]: B: Lab report writing **improves over time, from freshman to senior years**.

Author
Comment [6]: V: **Practice leads to improvement**

Author
Comment [7]: D: IMRAD

Author
Comment [8]: B: Everybody does it that way. So it's "the only way to do it."

Author
Comment [9]: B: Deviation from IMRAD = "mis-structured"

Author
Comment [10]: V: "**Coherence**," "**flow**"

Author
Comment [11]: B: Organization = "like reading a book"

chapters, and then you can go through all of those things without reading everything, so....

K: Okay. What do you think the features of a satisfactory lab report are?

S4: Hhmmm. I think the lab reports, if you look at some, 'cause I think that was in my Freshman year, we did have to, I think it was the middle of my first semester of my first year in university, they actually made us, uh, pass around our lab reports and then look at other people's and see what other people are doing. So, then when you look at them, everything from pretty much the Intro, Materials, Procedures, those are, everyone's pretty much the same 'cause you know what you're doing. But then where it changes, and where it gets really, really varies is actually the Results and the Conclusion 'cause that is what you, that's what you believe to be important in terms of this lab 'cause in the Results, you can pretty much put as much or as little as you want in there, as long as it supports your hypothesis, and it supports what you're trying to say, but if you look at everything there, it's like, "Oh, I didn't know that." And when you're looking at other people's like, "Is that important? Sometimes you think, you can leave that out, and you're like, "Oh, I had to think about that thing." And then your Results and your Conclusion is, I think in terms of professors and their point of view, they would look at what you think would be the key points as to how they would support your hypothesis, and support your main purpose of that experiment, of the lab. And that is all shown pretty much in your Results and your Analysis and Conclusion, those things, those parts, so um, personally, I think I would maybe kinda skim through the first parts 'cause they're gonna be pretty much the same from student to student, where it varies is the Results and Analysis and their Conclusion 'cause then it's gonna tell you how much you actually understand what you're doing, and what the purpose of this lab is 'cause you're gonna be writing about, "This is what happened. Why and why not?" Things like that, and that's I think, that much is, they would want the students to focus heavily on those parts. They're really, they're usually the most points are out of that too, the Results and Analysis. That's what they also heavily weigh as well. So, then you kind of understand that they do look for something there. And those things, but yeah.

K: Okay. What do you think the features of an unsatisfactory lab report are?

S4: Oh. The unsatisfactory?

K: Yes.

S4: Um, we've gotten criticized about this, I remember, um, because the Results, the Results is pretty much putting your graphs and your tables into words, so literally, people would put it into words, like one gram of this gave us this much of that, and the next sentence two grams of this gave us..... So, they

Author
Comment [12]: D: Students "**pass around**" or exchange lab reports to see how other students approach the assignment

Author
Comment [13]: D: **Epiphanies = exchanging lab reports and discussing**

Author
Comment [14]: B: Lab report exchanges and **peer review** most helpful with Results, Analysis, and Conclusion

Author
Comment [15]: D: "Results and Analysis" constitute **most points out of the lab report; most critical parts** of lab

do tell you to literally write in words your datas, your data into sentences 'cause datas are just numbers, your numbers and your results. And the results, they want you to put the numbers into sentences, what happened. But what people, I found doing were, they literally just put sentence one, one gram of this, gave us this, this, and this. Two grams of this gave us all of that, and that was the end of the Results. So, if you look at, if you look at what they want you to write in the Results, they did it right 'cause that's what they want you to do, but they were looking more in terms of like, what actually happened. They want you to put your, what you learned in class, and what you learned textbook based, also in there, not just regurgitating your numbers, and those things, and then after that, your Conclusion would be why do you think that happened, or why it didn't happen, or why did it not happen. So that, if you just say like, oh, because like if you look at the Introduction, and then the general background of your experiment, that will tell you why you're doing this, so then the Conclusion, people just look at that, and be like, "Oh, because we want to find out, this, this, this, and this." But there's so much more you should be writing about why it's important, and how you can apply it to real life, or what we could've, what we could've, um, for the reviewed, and things like that, so there were, I remember getting criticized from my professors that we were missing all those things, but there's just some things you have to get criticized on in order to know. Because we would have never known, we would have been finished with one gram, two gram, three gram, and be done. Um, I think that if teachers they will mark you heavily on those parts, I think, and also on what your results are.

Author
Comment [16]: B: Results should include "**what you learned in class**" and from the "**textbook**"

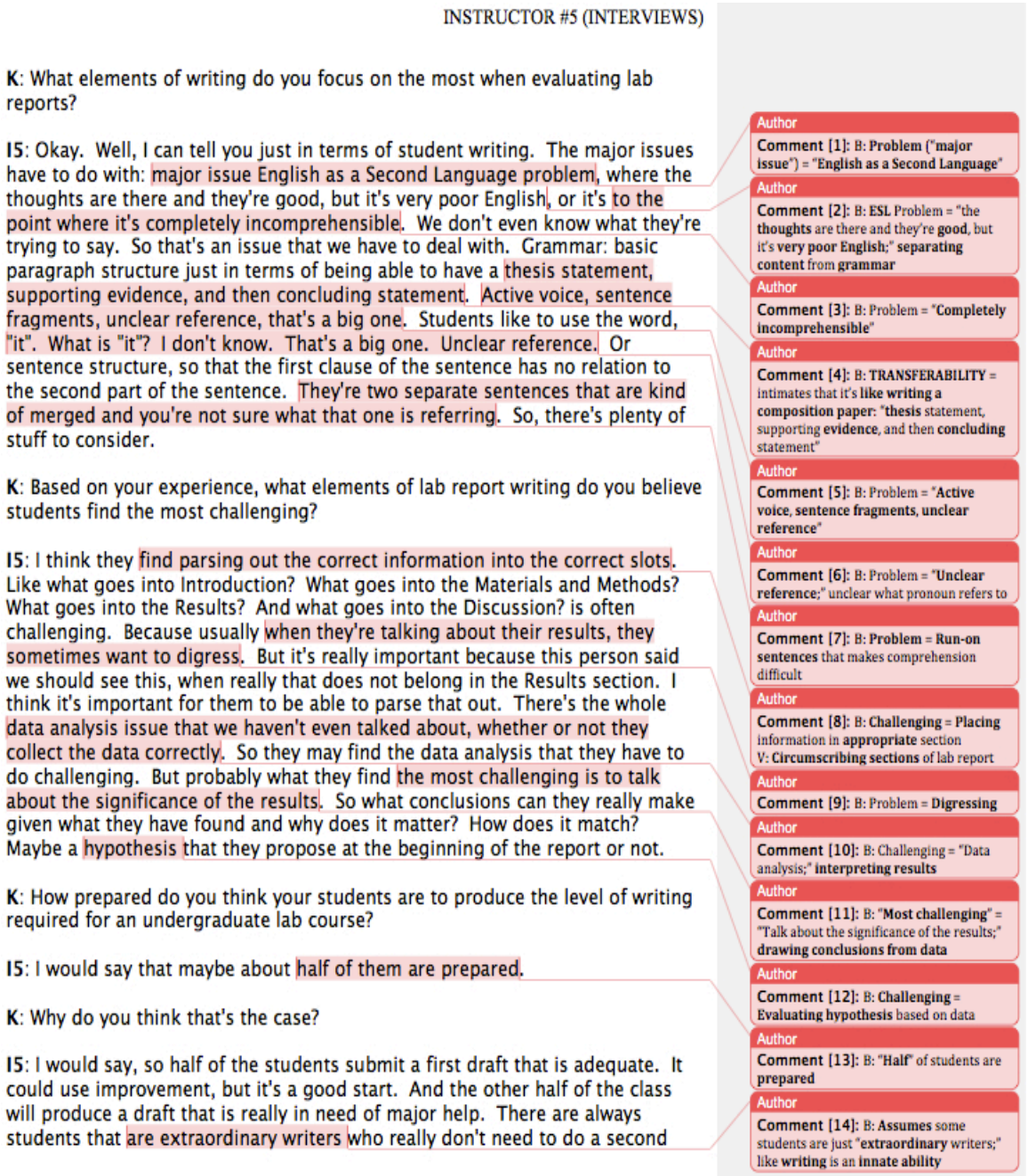
Author
Comment [17]: D: "Conclusion" explains **WHY** something happened

Author
Comment [18]: B: "Conclusion" explains "**WHY** it's important, and how you can apply it to **real life**"

Author
Comment [19]: B: **Criticism is productive** because it leads to **knowing what to do next time**

Author
Comment [20]: B: Teachers are most **critical** on parts they assign the **most points** to.

APPENDIX Q: CODING EXCERPT OF INSTRUCTOR INTERVIEW



INSTRUCTOR #5 (INTERVIEWS)

K: What elements of writing do you focus on the most when evaluating lab reports?

I5: Okay. Well, I can tell you just in terms of student writing. The major issues have to do with: major issue English as a Second Language problem, where the thoughts are there and they're good, but it's very poor English, or it's to the point where it's completely incomprehensible. We don't even know what they're trying to say. So that's an issue that we have to deal with. Grammar: basic paragraph structure just in terms of being able to have a thesis statement, supporting evidence, and then concluding statement. Active voice, sentence fragments, unclear reference, that's a big one. Students like to use the word, "it". What is "it"? I don't know. That's a big one. Unclear reference. Or sentence structure, so that the first clause of the sentence has no relation to the second part of the sentence. They're two separate sentences that are kind of merged and you're not sure what that one is referring. So, there's plenty of stuff to consider.

K: Based on your experience, what elements of lab report writing do you believe students find the most challenging?

I5: I think they find parsing out the correct information into the correct slots. Like what goes into Introduction? What goes into the Materials and Methods? What goes into the Results? And what goes into the Discussion? is often challenging. Because usually when they're talking about their results, they sometimes want to digress. But it's really important because this person said we should see this, when really that does not belong in the Results section. I think it's important for them to be able to parse that out. There's the whole data analysis issue that we haven't even talked about, whether or not they collect the data correctly. So they may find the data analysis that they have to do challenging. But probably what they find the most challenging is to talk about the significance of the results. So what conclusions can they really make given what they have found and why does it matter? How does it match? Maybe a hypothesis that they propose at the beginning of the report or not.

K: How prepared do you think your students are to produce the level of writing required for an undergraduate lab course?

I5: I would say that maybe about half of them are prepared.

K: Why do you think that's the case?

I5: I would say, so half of the students submit a first draft that is adequate. It could use improvement, but it's a good start. And the other half of the class will produce a draft that is really in need of major help. There are always students that are extraordinary writers who really don't need to do a second

Author
Comment [1]: B: **Problem** ("**major issue**") = "**English as a Second Language**"

Author
Comment [2]: B: **ESL** Problem = "the **thoughts** are there and they're **good**, but it's **very poor English;**" **separating content** from **grammar**

Author
Comment [3]: B: Problem = "**Completely incomprehensible**"

Author
Comment [4]: B: **TRANSFERABILITY** = intimates that it's **like writing a composition paper:** "**thesis** statement, supporting **evidence**, and then **concluding** statement"

Author
Comment [5]: B: Problem = "**Active voice, sentence fragments, unclear reference**"

Author
Comment [6]: B: Problem = "**Unclear reference;**" unclear what pronoun refers to

Author
Comment [7]: B: **Problem** = **Run-on sentences** that makes comprehension difficult

Author
Comment [8]: B: **Challenging** = **Placing** information in **appropriate** section
V: **Circumscribing sections** of lab report

Author
Comment [9]: B: Problem = **Digressing**

Author
Comment [10]: B: Challenging = "Data analysis;" **interpreting results**

Author
Comment [11]: B: "**Most challenging**" = "Talk about the significance of the results;" **drawing conclusions from data**

Author
Comment [12]: B: **Challenging** = **Evaluating hypothesis** based on data

Author
Comment [13]: B: "**Half**" of students are **prepared**

Author
Comment [14]: B: **Assumes** some students are just "**extraordinary** writers;" like **writing** is an **innate ability**

draft. But they're really in the minority. I would say about half of the students need major help, and a lot of them are native English speakers.

K: Do you provide any resources to your students about writing lab reports?

I5: For their writing assignments they do, we have a learning assistant that they can go talk to critically for English as Second Language Learners if they need someone to read it. But we also refer them to the writing center. For people, we definitely try to identify them early on, the people with major problems, and say "You need to do more work outside of class. And you need to go maybe make recurring appointments with the writing center tutor."

K: Do you find that helps them?

I5: I don't have enough contact with students these days. My T.A.s do so they know if it actually makes a difference for students who are really far behind, or for students who have major English problems. I haven't tracked them.

K: Have you found it necessary to give lessons on writing lab reports to your students?

I5: My T.A.s are starting to do some neat things in Recitation where we do peer review with the rubric, so the students swap and they grade each other's, and that's a big eye opener, so there's some self-reflection that goes on. And then we also have them write on the board, traits of good writing. So there's some discussion among the students after they've seen some examples. We also work with a standard set of a good, medium, and really poor writing example, the first recitation, so they can see what good writing looks like, and what very poor writing looks like, and they all have to use the same rubric and then we discuss the traits of them.

K: What are one or two pieces of writing advice you find yourself giving most often to students writing lab reports?

I5: When I've graded the recent write ups, "Read this out loud to yourself and ask yourself if this makes sense." Often, students can express themselves fairly articulately, but when you actually read what they've written, it makes no sense, so my guidance to them, "Read this out loud to someone verbatim, and ask yourself if it is expressing what you want it to." So, it provides some reflection on what you've written. Just don't hammer it out. The other, I would say, unclear reference. They can often be very vague, and I'm not quite understanding what the meaning in their sentence is. I guess that ties into the first point. Just very unclear reference. Bad active voice and vague.

Author
Comment [15]: D: Resource = "learning assistant" who focuses on writing

Author
Comment [16]: D: Resource = "**Writing center**"

Author
Comment [17]: B: **Goal** is to **identify** students with major language problems (**ESL**) **EARLY**;
B: Student's **RESPONSIBILITY** to **correct language problems outside of class**
B: **Not teacher's responsibility** to teach **grammar**

Author
Comment [18]: D: Teach writing in "**Recitation**"

Author
Comment [19]: D: "**Peer review** with the **rubric**;" students **use RUBRIC** as guide

Author
Comment [20]: D: Students "**GRADE**" **each other's papers**

Author
Comment [21]: B: Students practicing "**self-reflection**"

Author
Comment [22]: D: Classroom **discussion** of "**good writing**"

Author
Comment [23]: D: "**Discussion** among students" = **peer review**

Author
Comment [24]: D: Show **sample** lab **reports**

Author
Comment [25]: D: Show "**good, medium, and really poor**" **examples** of lab reports (first recitation, **EARLY**)

Author
Comment [26]: B: Advice = Reading lab report out loud to yourself, and asking if they are writing what they intend to say; **read out loud** and **ask questions** about **meaning**

Author
Comment [27]: B: **Mismatch** between **SPEAKING** and **WRITING** abilities

Author
Comment [28]: V: "**Reflection**" on writing

Author
Comment [29]: B: Students should **avoid** "**active voice**," and **vagueness**

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