

THE EFFECTS OF TECHNICAL WRITING STRATEGIES ON STUDENT WRITING
AND SCIENTIFIC COMPREHENSION

by

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DEDICATION

This classroom research project is dedicated to Carol Lehmann, my mother, who was one of the most outstanding educators of children I have had the privilege of knowing, and Robert Lehmann, my father, who first encouraged my love of science.

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I would like to thank my family and colleagues who have helped me achieve this goal. First, I would like to acknowledge my children, Tal, Zeb, and Katie for their continued patience and sacrifice. The following individuals assisted in the completion of this classroom research project. Kyle Hutson (HPC System Administrator/College of Engineering Faculty, Kansas State University) served as proofreader and as an expert in data analysis, and assisted me in looking for patterns in my data. Emily Krstulic (ELA Instructor, Blue Valley High School) helped me modify the Idea and Content Rubric for use in the science classroom. Michael Lee (Science Instructor, Blue Valley Middle School) was also pursuing a Masters degree in ESL through Pittsburg State University (Pittsburg, KS) and so was current in educational theory and methods of best practice. We collaborated on a frequent basis to ensure alignment between our classes. Michael provided much needed feedback. As a new graduate and teacher in the profession, Anthony Meals (Agriculture Education Instructor, Blue Valley High School) provided valuable insight into what type of writing was required by university professors. I would also like to express my thanks to Dr. Peggy Taylor, MSSE director, and Diana Patterson, MSSE associate director. Both made my time in the MSSE program easy to navigate. I appreciate their professionalism and support. Finally, I would like to thank Dr. Kathryn Apley and Dr. Walt Woolbaugh for their expertise in experimental design. Without their continued support and encouragement, this process that I began so many years ago would not have been possible.

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ABSTRACT

For this research project, two writing strategies, Self-directed Inquiry (SDI) and Calibrated Peer Review (CPR), were evaluated to determine which strategy would be most effective in improving students' technical writing and science comprehension.

Students from a small rural high school in Northeast Kansas (N=49) were evaluated. Class sizes ranged from three to sixteen. The data collection techniques included individual interviews, student surveys, Classroom Assessment Techniques (CAT) assessments, a teacher reflection journal, student writing samples assessed with both a Content and Ideas Rubric and Curriculum Based Measurement (CBM), and comparison of pre-test and post-test scores. For one week, students learned through traditional classroom teaching methods in a comparison unit delivering content about Yellowstone National Park. It was followed by six weeks of implementing SDI, in which students learned about the biology, geology, and chemistry of the thermal features of Yellowstone National Park. Finally, for two weeks, students studied about the models scientists use to explain a primordial Earth using CPR.

Results revealed that CPR was very effective in increasing students scientific comprehension based on normalized gain. Responses from student surveys indicated that they enjoyed using this approach to technical writing. Results were inconclusive regarding the effectiveness of the SDI approach to technical writing. There was no significant increase in student comprehension based on normalized gain when SDI was compared to the comparison group. In addition, student surveys indicated that they did not prefer this method to other technical writing approaches. More study is needed to determine how to best implement SDI in a high school science classroom.

INTRODUCTION AND BACKGROUND

Writing is an important skill as successful writers are highly valued in the workplace. When students get stuck in the writing process, it can really stifle their learning, especially if writing is a primary means of communicating what students know. As students become better writers, they gain confidence in their increased ability to share their ideas and findings. All students need to write technically whether or not they pursue a career in science. In order to be better able to assess my students, they need to clearly express their ideas and understanding of science content. When students are able to synthesize science content by writing, they will be able to make connections between the science disciplines and better understand the themes that are important to each field of science. They will also be better able to communicate those scientific ideas to the general public. Possessing this skill can be applied to other types of technical writing.

Giving students several tools and scaffolding from which to draw will help them with the writing process. From local observational data, it was noticed that many struggling writers do not complete assignments. Since the adoption of the Next Generation Science Standards by Kansas in 2013, it was also noticed that all writers at Blue Valley High School, USD 384, had problems making connections with the Disciplinary Core Ideas, Cross Cutting Concepts, and the Big Ideas from the units of study. It was also noticed that all students could improve their writing. This was an important area of research locally because the majority of students from Blue Valley High School attend either technical schools or universities. This district requires students to take four science credits to graduate. Students at Blue Valley High School have one

primary high school science teacher for four years. The same teacher evaluates their technical learning and writing skills progress as they mature. From interviews with former graduates, it was found that one of the areas in which they struggle the most was writing scientifically.

Research Questions

The research questions for this study were as follows:

- What strategies can best help struggling writers improve their technical writing over a nine-week time span?
 - How can scaffolding prompts help all writers improve their technical writing?
 - What are the effects of improved technical writing on student's scientific reasoning?
- What are the effects of improved technical writing on the classroom teacher?
 - In what ways do I play a role in my students' ability to organize their thoughts and share them through the written word?
 - How can I improve my practice to aid students in becoming better writers?

CONCEPTUAL FRAMEWORK

According to the National Commission on Writing (College Board, 2004), writing is an important hiring consideration by many employers. With the essential skill of good writing, students will not only gain employment, but they also have a greater chance of being promoted. People who lack the ability to write and communicate clearly will not be hired. Even if they are hired, they will not be employed long enough to be considered for

a promotion. In the world of work, as well as postsecondary education, people must frequently produce “technical reports, formal reports, memos, and correspondence.” In addition, writing emails can be a daily occurrence (College Board, 2004).

DeMillano, van Gelderen, and Slegers (2012) wrote about struggling writers’ difficulty in self-regulating their writing process. They, therefore, had a hard time completing long writing assignments. In this study, a group of struggling writers (N=51, ages 13-15 years) were interviewed about the types of things that they did to self-regulate their writing process. The focus of the study was to find the techniques used by less proficient writers to regulate their writing process and how that self-regulation affected the quality of the text written. It was found in the study when struggling writers were taught to spend more time planning and formulating what they wrote, they succeeded in writing better papers. By allowing a student to think aloud as he or she wrote, students wrote better products.

Olinghouse and Santangelo (2010) reviewed several instructional strategies and outlined the need for good assessment practices to help target where individual students who struggle with writing need to improve. The authors also outlined assessment methods that teachers can use to determine a more personalized instructional program to help individual students improve the areas of writing in which they struggle. The authors related that in teaching writing there should not be a one size fits all writing assessment.

By evaluating students’ individual writing products and process using spelling, vocabulary, sentence and text levels, and other writing elements, teachers could determine in what areas to target student improvement. The authors recommended the

establishment of individual goals and the use of a writing portfolio in which copies of student works were kept. This review of the educational literature discussed methods to be used with elementary, middle, and high school students. In addition to the writing portfolio, the authors recommended using Curriculum Based Measurement (CBM) to evaluate the mastery of student writing goals. CBM uses a number of probes that help both teacher and student identify if a writing goal has been mastered. CBM dealt mostly with the use of proper conventions and did not address the writing process (Olinghouse and Santangelo, 2010).

Using *Writing Across the Curriculum* (WAC), McLaren and Webber (2009) reported concerning their comparison of performance and engagement of two student groups in an Ecology course at the University of the West Indies, Jamaica (Treated group N=41, Non-treated group N=75). The treated students were subdivided into one of two groups. To improve the writing in lab reports, one group of students were given the other group's written lab from the previous week. They were asked to conduct the lab following the description given in the lab report. Students found that not enough detail was given and the original writers needed to revise their work so their peers could understand their instructions. Independent sample t-tests were carried out to determine if there were significant differences between mean scores in the treated and non-treated groups. As compared to the non-treated group, there were no significant differences in the treated group. As noted by the authors, this may be because of the sporadic writing of students in the treated group. Only half of the students in the treated group completed the revision. When the treated group was further subdivided into students that followed the

revision process (N=16), it was found there was a significant difference in scores between the treated group and the non-treated group. This study reinforced the importance of requiring students to revise and rewrite their technical writing. Students who were actively engaged in writing had a pass rate of 93% as compared to a pass rate of 50% the previous year. The authors did note some limitations to the WAC strategies. These were that gains in knowledge could have been due to the subgroup of students already being particularly good writers. They also could have had a lot of previous writing experience and so were more comfortable with writing (McLaren and Webber, 2009).

In her 2013 paper in the *Annals of Dyslexia*, Jill Fitzgerald explored the connection between reciprocal reading and the composing processes applied by writers to explain the nature of learning. She evaluated four studies based on the knowledge and processes that were emphasized in the act of writing. First, she considered whether the composing process (the act of writing) is conscious or unconscious. She further subdivided the act of writing into five subcategories. Successful writers knew about the functions and purposes of composing. They monitored how their responses have meaning for the reader through their metaknowledge and pragmatics. They had a large amount of prior knowledge and procedural knowledge (the ability to access, use, and create knowledge as well as find new ways to link knowledge). They also knew what characteristics of a written response (letter and word generation, sentence syntax, paragraph and document organization) make it more easily read. Good writers planned their writing. They transcribed their sources into their own words and summarized findings. They also reviewed what they have written and revised it for clarity. Finally,

they understood how to express their ideas and emotions so the reader could relate to their position (Fitzgerald, 2013).

Fitzgerald also looked at where researchers think those processes reside in the brain. From her review, she found that it is accepted that most writers may not consciously be able to explain their process of writing. This was especially true of struggling writers. However, it was reported that struggling writers can overcome their disposition to poor writing and be taught strategies to make them better writers. It was also concluded that good writing could be taught outside of the writing process. The entire process could be broken into smaller parts and taught using smaller responses to help students gain mastery in the parts of the writing process in which they are struggling. Finally, she considered how students gain those skills to make them proficient writers (Fitzgerald, 2013).

Denier, Newsome, and Samaroo (2012) also described an educational technique to aid students in the scientific writing process particularly in the writing of inquiry lab reports. A scaffold was developed by the authors to assist undergraduate chemistry students in the writing of lab reports. Over the course of fifteen labs, students went from writing a lab report with no particular format to a full lab report (including title, abstract, introduction, results, discussion of results with analysis, conclusion, and references). The authors found that after working with the direct self-inquiry scaffold that 65% of the class (N=48) received a developing to accomplished score on their final lab report. Twenty percent of the class (N=48) received a beginning to developing score on their final lab and fifteen percent of students received an accomplished to exemplary score on their final

lab report. The authors were encouraged with the use of this scaffold as a tool for students to use to become better scientific writers.

Calibrated Peer Review (CPR) allows for student summary of lengthy technical writing as described by Hartberg, *et al* (2008). CPR was used to improve student writing in a senior-level biochemistry class (N=50). The study evaluated the effectiveness of CPR as compared to TA evaluated assignments. It also compared CPR results between males and females to see if there were marked differences (N=256). CPR is a web-based program that was developed at UCLA for the Molecular Science Project. Its purpose was to give students practice in writing and evaluating their classmates writing through peer review. Once students submitted their papers, they were given sample papers and asked to evaluate them using a rubric. Students received feedback on their reviews and were asked to anonymously review their peers' writing. Every student's paper was peer reviewed by three classmates. Students also completed a self-evaluation of his or her paper. To determine the effectiveness of the method, quantitative analysis of students scores were considered. The instructor also kept a teaching log to document the process. Students wrote four papers throughout the semester long course. Peer reviewed abstracts were compared to abstracts from the previous year that were graded by a teaching assistant (TA). A statistical analysis showed that there was a significant difference of improvement in writing when comparing the CPR evaluated papers to the TA evaluated papers. There were no significant differences between the writing of males and females. There was a statistically significant improvement in the CPR generated scores.

METHODOLOGY

Description of Treatment

The time frame for this project was from January 4, 2016 through March 8, 2016. To determine how best to improve student technical writing skills, I implemented two teaching strategies to give students a variety of methods to help them in the planning of their writing process and revision of their writing process. Over a two-month period, students completed five formal written lab reports following Denier's guidelines (2012) and two peer reviewed abstracts following Hartberg's guidelines (2008).

The first teaching strategy I implemented was the use of a method of scaffolding in the writing of lab reports as documented by Denier, *et al* (2012). Over the course of fifteen labs, students went from writing a lab report with no particular format to writing a full lab report (including title, abstract, introduction, results, discussion of results with analysis, conclusion, and references). In my classroom, I used this strategy to help my students write their formal lab reports. During a four-week period, students conducted and completed five mini-labs. They reported the findings from those mini-labs following a modified reporting approach based on the work of Denier, *et al* (2012). While intended for post-secondary students, the scaffold developed by Denier, *et al* appeared to be ideal for helping my students with the writing process. Through my informal observations, I felt this is the area in which my students struggle the most. While the method described in this study may be helpful in the improvement of formal scientific writing, it did not meet all of my needs.

Since the methodology described in the Denier, *et al* study (2012) did not

completely satisfy the requirements for a lengthy technical writing assignment and how it could be evaluated, I used the Calibrated Peer Review (CPR) as described by Hartberg, *et al* (2008) where students wrote an abstract of a research study. In my classes, over a two-week period, students were required to complete one research summary and evaluate one paper written by their peers with CPR. Students completed a self-evaluation of their own review and then anonymously reviewed one of their peers' abstracts.

Description of Research Methods

To determine how much my students' writing improved, I used several methods of measurement including comparison of improvement based on pre-test and post-test scores, student writing assignments, daily classroom assessment techniques (CATs), Likert-style student attitude surveys, an Idea & Content Rubric, Curriculum Based Measurement (CBM) Probes, individual student interviews, and a teacher log.

To evaluate content knowledge and scientific reasoning, a pre-test and post-test was given to all 49 students at the beginning and ending of each treatment. Differences in scores between pre-test and post-test were compared using Welch Two Sample t-test.

To sample the improvement in student writing, I used classroom assessment techniques (CATs), examples of students' writing assignments, and data collected from CBM results and peer reviews (CPR). These were the primary quantitative assessments of the students' technical writing skills. Student writing assignments were evaluated using two different grading methods. The first was an Idea and Content Rubric (Appendix A), which was developed in conjunction with the English teacher at my high school and was used to evaluate student writing in English, Science, and Social Science

at my high school. Results from Content and Idea Rubrics for all written assignments were analyzed for patterns. The second method was CBM (Olinghouse and Santangelo, 2010), which involved the analysis of student use of task and domain specific vocabulary to enhance their writing. CBM used a number of probes (Appendix B) that help the teacher identify if the use of task specific vocabulary had been mastered. Using the CBM data, student writing was analyzed to determine their level of comprehension based on their task/domain specific vocabulary score. A comparison of student CBM task/domain specific vocabulary scores and normalized gain on posttests was performed to determine if there was a correlation. Results were compared. To aid students in their organization skills, a Calibrated Peer Review Rubric was developed (Appendix C). It was based on existing models, but modified for a high school classroom setting.

Throughout this classroom research project, three Likert-style student attitude surveys (Appendix D-Appendix F) were given (1 pre-treatment survey and 2 post-treatment surveys) to gain qualitative data on students' attitudes toward technical writing. These pre and post Likert surveys were given to the entire group of students (N=49). The Likert student survey was administered to determine student attitudes on technical writing and how they prepare for the writing process. Students were asked to rate their feelings on a scale of five to one where five was strongly disagree and one was strongly agree. After a brief description of the instrument and its purpose, all students were given the survey at the beginning of class and asked to respond as part of their bell work. Absent students were given the survey the following day as bell work. Once students were finished with the survey, they submitted it to the teacher. While all responses were

anonymous, each survey was assigned a student number for later analysis, if necessary. Within the Likert survey, there were several free response questions with which students could provide more information about their reasoning or examples that would support their response. Most respondents took between five to ten minutes to respond to the survey. A few respondents asked to revisit them later in the day to add comments to the free response questions. The student surveys provided data about students' opinions of writing and the use of these writing method helping their improvement in the skills of planning, organization, and revision in the writing process. After piloting these data collection methods, it was determined that more questions needed to be added to the survey to increase validity. Also, open-ended questions needed to be added to the last portion of the student survey. While it is understood that no instrument is perfect, it was difficult to know what students were thinking due to their responses that dealt with revision and peer editing. This was especially important due to the conflicting data that had been received when student-writing samples were compared to student survey responses. Revised student surveys were developed (Appendices D-F). Student responses were analyzed based on the following categories: student thoughts about the particular writing treatment (i.e. No treatment, Self-directed inquiry, or Calibrated Peer Review), student writing process, student revision habits, and student expression of ideas.

Individual student interviews (N=5) were given to probe for further information. Selection of these individuals was due to their responses to the preliminary Likert assessment given in 2015. Students were identified as struggling writers and were asked questions regarding the planning process they used before they write and the tools and

skills they used when revising their work. More detailed interviews were conducted to determine their writing mindset. Students' pre-treatment and post-treatment interviews were recorded and transcribed into a word-processing document. The student interview questions can be found in Appendix G. The six numbered questions were asked of each student. Probing questions were added during the interview, if necessary. These were lettered and underneath the numbered questions. Questions were reworded so that the interviewees better understood what was being asked of them. All students were interviewed using a modified focus group. The five students were previously part of my Learning Academy that was a cross section of the school. In this focus group, there were three male students and two female students. There were four sophomores and one junior.

To gain knowledge of the process and assess the value of this Action Research for myself, I kept a reflective teaching log. The log was analyzed for patterns in students' comments and behaviors that gave me insight into how valuable certain teaching strategies were in improving student technical writing. I also used my Teacher Log to record anecdotal evidence and reflections about my practice.

Using these eight sources gave a global way to determine not only if student writing was improving, it also helped me conclude in what areas student writing needed to continue to improve (i.e.: conventions, content and ideas, etc).

The matrix (Table 1) summarized the methods in which each data collection tool supported my research questions. To ensure the validity of the instruments used in this classroom research project, I defined a struggling writer as one who failed to complete writing assignments or submitted writing assignments that failed to answer a majority of

the aspects of the suggested writing prompt as described on the Ideas and Content Rubric (Appendix A). To ensure the reliability of the instruments used in this classroom research project, I used the retest method in which the same instruments are used to assess improvement in student writing and comprehension throughout the entire study at the end of each treatment (Table 2).

Table 1
Triangulation Research Matrix

Research Questions	Data Sources								
	1	2	3	4	5	6	7	8	9
	Pre/Post Test	Student Writing Assignments	Daily CATs	Likert Student Survey	Idea & Content Rubric	CBM	CPR	Student Interview	Teacher Log
What strategies best help struggling writers improve their technical writing over a nine-week time span?		A, B, & E	A & B	C	A & B	A & B	A & B	C & D	D
How can scaffolding prompts help all writers improve their technical writing?			A & B		D	D	D		A & B
Will improved technical writing increase students' scientific reasoning?	D			C	C & D	C & D	D		
What are the effects of improved technical writing on the classroom teacher									D
In what ways do I play a role in my students' ability to organize their thoughts and share them through the written word?									D
How can I improve my practice to aid students in becoming better writers?									D

Note. Key to identify reasons why the data method selected was suited to gather data for which the question was matched.

- A) Data showed change in student's written work
- B) Data showed samples of student's work over time.
- C) Gave qualitative data of student opinions and self-evaluations.
- D) Data reflected the value of the treatments
- E) Data provided an example of students writing ability prior to the treatment

Table 2
Timeline for Study

Activity	Treatment?	Topic	Tentative Dates
Begin Teacher Log			
Lessons 1-4	No Treatment	The World of Extremophiles	1/4-1/8
Tally student scores on pre and post tests			
Evaluate student writing assignments using Idea and Content Rubric/CBM rubric			
Administer Likert Survey and daily CATs			
Reflect in Teacher Log			
Conduct Student Interviews			
Lessons 5-10	Treatment: Self-directed inquiry (Denier, 2012)	Site Analysis and Model Building	1/11-2/29
Tally student scores on pre and post tests			
Evaluate student writing assignments using Idea and Content Rubric/CBM rubric			
Administer Likert Survey and daily CATs			
Reflect in Teacher Log			
Conduct Student Interviews			
Lessons 11-15	Treatment: Calibrated Peer Review (Hartberg, 2008)	What Type of World Was It?	3/1-3/10
Tally student scores on pre and post tests			
Evaluate student writing assignments using Idea and Content Rubric/CBM rubric			
Administer Likert Survey and daily CATs			
Reflect in Teacher Log			
Conduct Student Interviews			

Sampling Strategies

A variety of sampling strategies were used to provide both formative and summative evaluations of the research questions. Because my classes were small in size and I was the only science teacher at my high school, I evaluated all of my high school science students (N=49). Our school population was 53% female and 47% male. The families at Blue Valley High School ranged in socio-economic status from lower middle

class to upper middle class. 32% of families were on free or reduced lunch. The demographics of the student population were African-American 0%, American Indian 0%, Asian-Pacific Islander 2%, Caucasian 94%, Hispanic-Latino 2%, and Mixed Race 2%. 12% of students were on an Individualized Education Program (IEP). Seven seniors, fourteen juniors, thirteen sophomores, and fifteen freshmen were included in this study. The research methodology for this project received an exemption by Montana State University's Institutional Review Board (Appendix H) and compliance for working with human subjects was maintained.

DATA AND ANALYSIS

Student Growth

Pre-unit and post-unit content assessments were given for both treatment and comparison units. The results for all students do not show statistically significant growth between the comparison unit and unit taught using Self-Directed Inquiry (SDI). However, there was statistically significant growth between the comparison and unit taught using Calibrated Peer Review (CPR).

Table 3 summarizes the unit findings. While scores improved from pre-test to post-test regardless of treatment, the greatest improvement was seen in the CPR unit.

Table 3
Summary of Findings from Study (N=49)

<u>Treatment</u>	<u>Mean</u>	<u>Median</u>	<u>Range</u>	<u>Variance</u>	<u>Std Dev</u>
Comparison (before)	44.9	40.0	80.0	329.7	18.2
Comparison (after)	71.4	73.0	73.0	249.7	15.8
Self Directed Inquiry (before)	34.1	38.0	75.0	508.5	22.6
Self Directed Inquiry (after)	60.8	64.0	64.0	231.3	15.2
Calibrated Peer Review (before)	24.0	29.0	57.00	177.72	13.3
Calibrated Peer Review (after)	64.0	65.0	60.0	189.2	13.8

Figure 1 further compares raw pretest and posttest scores for both treatment and non-treatment units using a boxplot. Values on this boxplot include (from top to bottom on the box and whisker) quartile three, the median, and quartile one. The median is higher in the comparison group, but the median does fall within the range of both treatment groups when variance in the test scores are considered. There is one outlier that exists in the comparison and several that are seen in the Calibrated Peer Review treatment.

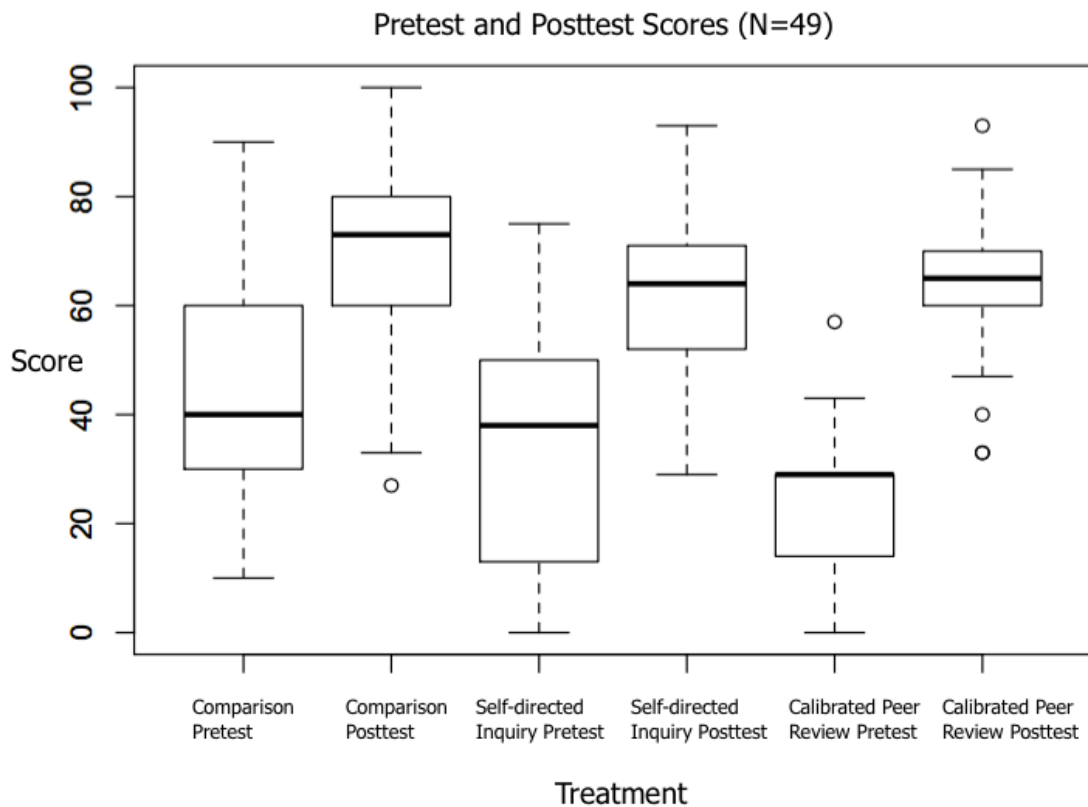


Figure 1. Results showing a comparison between non-treatment and treatment pre-test and post-test scores, (N=49).

When considering the results shown in Table 3 and Figure 1, it was apparent that the Self-Directed Inquiry unit showed the most variance between scores. At first glance, it was thought that this might be due to either the difficulty of the subject matter or the inexperience of a portion of the students with the inquiry process. All students were very unfamiliar with the subject matter that was taught in the comparison and treatment groups as shown by the range in pretest scores (Figure 1). Both freshmen (N=15) and sophomore (N=13) classes had limited experience with inquiry learning. From teacher observations, both these subgroups struggled more with the daily tasks than the upperclassmen. Many of the students failed to take the care necessary to get comparable data as shown by examples of student work. Both junior (N=14) and senior (N=7) classes had more experience with inquiry learning. However, they also struggled with the incorporation of methods to fully complete the inquiry project. The Calibrated Peer Review unit had much more structure in the method of presentation and expectations. All classes were thought to have made better achievement based on their post-test scores.

To determine the amount of actual student growth, post-test scores were adjusted using the methodology for corrected normalized gain for guessing as suggested by Stewart and Stewart (2010). Adjusted scores are shown in Figure 2 (see next page). Values on this boxplot include (from left to right on the box and whisker) quartile three, the median, and quartile one. All three groups had outliers. The comparison group had the most extreme outliers, which showed that at least three students exhibited a reduction in their scores from pretest to posttest. They had a higher score on their pretest as compared to their posttest score.

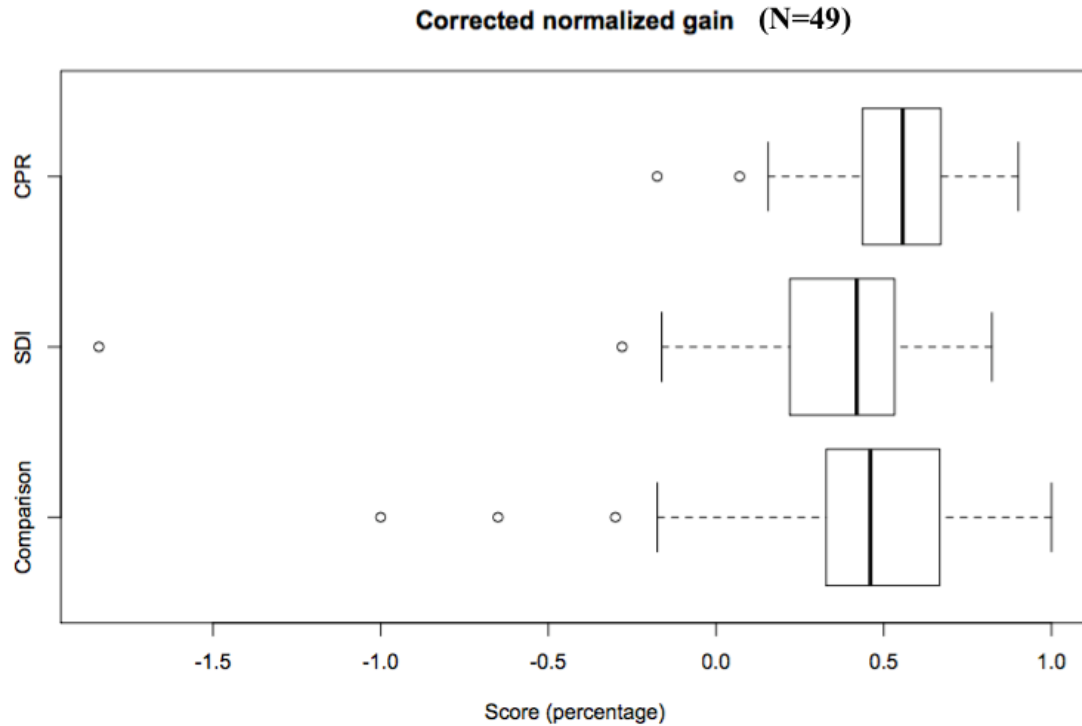


Figure 2. Comparison of normalized scores to compare student improvement, ($N=49$).

The comparison group (mean=0.42, median=0.46, std dev=0.38) showed the broadest range of scores, in which 77.5% of students ($N=38$) showed a medium to high level of improvement. The Self-Directed Inquiry (SDI) unit (mean=0.33, median=0.42, std dev=0.42) showed a range of scores similar to the comparison group. This treatment actually showed the least student improvement. There could be several factors that attributed to this small amount of growth. Throughout this treatment, students conducted five inquiry experiments in which the results from one lab determined how students proceeded in subsequent labs. Lab results were not independent. If a student group had difficulties at the beginning of the unit, the next portions of the unit were made more difficult. No amount of extra help seemed to clear up their preconceived notions. During the SDI unit, only 67.3% of students ($N=33$) showed a medium to high level of

improvement. More students demonstrated high to medium growth when the unit taught using Calibrated Peer Review was compared to the non-treatment unit. The most improvement in student scores was observed in the Calibrated Peer Review (CPR) unit (mean=0.55, median=0.56, std dev=0.21). During the CPR unit, 91.3% of students (N=42) showed a medium to high level of improvement. There were also several factors that attributed to the higher amount of improvement during the Calibrated Peer Review unit. This treatment had more structure and the content was less abstract. Fewer students were absent during this unit. Also, the results of each writing assignment during this unit were independent. Students reported their summaries to each other, taught each other their findings, and evaluated each other's work. Table 4 outlines the frequency of high, medium, and low growth among treatment and comparison groups.

Table 4
Frequency of Categories of Growth (N=49)

Treatment	High Growth (0.7-1.0)	Medium Growth (0.4-0.6)	Low Growth (0.1-0.3)
Comparison	11	27	11
Self-Directed Inquiry	5	28	16
Calibrated Peer Review	8	34	4

Adjusted student scores were also compared using the Welch Two Sample t-test to determine statistical significance. When non-treatment and Self-Directed Inquiry scores were compared, it was determined that there was no statistical difference between the mean of scores ($p=0.2975$). When non-treatment scores were compared to Calibrated Peer Review scores, it was determined that there was a statistically significant difference

between the mean of scores ($p=0.04211$). Because histograms of all groups (both treatment and non-treatment) showed a non-normalized frequency, scores were also evaluated with the Wilcoxon rank sum test with continuity correction. Using the Wilcoxon rank sum test, there was no statistically significant difference between the median of the comparison group and the median of the Self-Directed Inquiry group ($p=0.2243$). There was a statistically significant difference between the median of the comparison group and the median of the Calibrated Peer Review group ($p=0.086$). Based on this evidence, it is thought that Calibrated Peer Review is a more effective method by which students can learn and apply content than more traditional teaching. Based on the way it was presented, Self-Directed Inquiry was not shown to be more effective than traditional teaching methods for the entire student population. Although student scores did show improvement at the end of the Self-Directed Inquiry Unit, one cannot be certain that it was due to the application of the treatment.

To evaluate the hypothesis concerning student preparedness and maturity, data was also disaggregated by age, gender, and speciality to determine which treatment best served different sub-groups of the student population. Table 5 (see following page) shows normalized gain disaggregated by grade in school. Freshmen ($N=15$) did best under the Calibrated Peer Review with 100% of them having scores that showed medium improvement from their original pretest scores. 60% of the class showed medium to high improvement under the comparison group, while only 53% of the class showed medium to high improvement under the Self-Directed Inquiry treatment. Based on teacher observations, Calibrated Peer Review provided the structure this class needed. This class

struggled greatly with the Self-Directed Inquiry unit and had to repeat experiments to get valid data before moving to the next experiment. This proved to be very frustrating for many in the class as they could only think in terms of right or wrong and felt they were doing everything wrong. Faced with a wrong answer, many chose to not complete the final analysis and therefore, had a larger gap in learning. In addition, the freshmen did not have a rich understanding of how to analyze their data in order to determine patterns.

Table 5
Comparison of Frequency of Normalized Gain by Age

Grade	Treatment								
	Comparison			Self-Directed Inquiry			Calibrated Peer Review		
	Low	Med	High	Low	Med	High	Low	Med	High
Freshmen (N=15)	6	8	1	7	7	1	0	15	0
Sophomores (N=13)	0	8	5	3	9	1	0	9	4
Juniors (N=14)	2	7	5	3	10	1	4	9	1
Seniors (N=7)	3	4	0	3	2	2	0	3	3

The sophomore class (N=13) also did best under Calibrated Peer Review with 100% of students showing medium to high improvement in their scores. 76% of students had medium to high improvement of their scores under Self-Directed Inquiry, while only 62% of students had medium to high improvement during the comparison unit. This class liked the ease of the Calibrated Peer Review process and found it was more streamlined than the Self-Directed Inquiry unit. The sophomore class had more experience with inquiry activities as compared to the freshmen. However, they lacked some confidence in determining if their results were valid. They needed constant reinforcement. In addition, several students from this class performed the experiments leaving others in their groups to simply copy the data with no real understanding into what the data meant.

When looking at medium to high improvement of scores, the junior class (N=14) saw their most improvement in scores in the comparison unit (86%), followed by Self-Directed Inquiry (78%), and finally, Calibrated Peer Review (71%). This class has much more experience with inquiry activities, the protocols used to collect data, and how to treat uncertainty in data. They still struggled with the necessity to collect comparable data and the interrelatedness of the lab results.

Seniors (N=7) showed the most improvement of scores (both medium and high) in the Calibrated Peer Review unit (100%). They saw equal gains in improvement in both the Self-Directed Inquiry unit and the comparison unit (57%). This class also has more inquiry experience than the underclassmen. However, since they were in classes with the juniors, they tended to let the juniors run the experiments and did not have a great understanding of what the data was showing them. However, they were forced to more actively participate in the Calibrated Peer Review unit since everyone was required to complete two individual writing assignments.

Besides comparing age, normalized scores were compared by gender to determine which treatment was best for both males and females (Table 6). Females (N=26) showed no difference in scores regardless of treatment. Females had the most improvement in scores in the Calibrated Peer Review unit (88%), followed by the comparison unit (85%), and then the Self-Directed Inquiry unit (81%). Males, however, showed great variation in scores. Males performed better in the Calibrated Peer Review Unit (95%) than in the comparison unit (68%) and the Self-Directed Inquiry unit (50%).

Table 6
Comparison of Frequency of Normalized Gain by Gender

Gender	Treatment								
	Comparison			Self-Directed Inquiry			Calibrated Peer Review		
	Low	Med	High	Low	Med	High	Low	Med	High
Female (N=26)	4	15	7	5	18	3	3	21	2
Male (N=23)	7	12	3	11	9	2	1	16	5

During the Self-Directed Inquiry unit, females tended to run the show. Males did not always get to perform the experiments. Therefore, they did not have a rich understanding about the implications of the collected data. However, during the Calibrated Peer Review unit, all students worked individually on their abstract. They were required as part of this teaching strategy to teach their peers. Then they received feedback on their abstract from their peers before they rewrote their abstract for clarity.

Finally, students were compared by speciality: regular education (N=40), learning disability (N=6), and gifted/talented (N=3). Table 7 (shown on next page) summarizes those findings. 93% of regular education students saw a medium to high improvement in their scores in the Calibrated Peer Review Unit. 80% saw an improvement in the comparison unit and 68% saw an improvement in the Self-Directed Inquiry unit. Students with a learning disability also did best in the Calibrated Peer Review Unit. 83% saw a medium to high improvement in their scores. There were only 67% of learning disability students that had a medium to high improvement in both the comparison and Self-Directed Inquiry units. Gifted and talented students also did best in the Calibrated Peer Review Unit with 100% of students having a medium to high improvement in scores. The gifted and talented students found the subject matter fascinating and really liked teaching

their peers. They also appreciated the feedback from their peers on their abstracts. Only 67% of gifted and talented students saw a medium to high improvement in scores in both the comparison and Self-Directed Inquiry units. Since the gifted and talented students were a very small group, it was hard to determine why one student did poorly on the Self-Directed Inquiry unit. However, it is possibly due to inexperience with inquiry activities and how to evaluate patterns in data.

Table 7
Comparison of Frequency of Normalized Gain by Speciality

Speciality	Treatment								
	Comparison			Self-Directed Inquiry			Calibrated Peer Review		
	Low	Med	High	Low	Med	High	Low	Med	High
Regular Education (N=40)	8	24	8	13	23	4	3	31	6
Learning Disability (N=6)	2	3	1	2	4	0	1	5	0
Gifted/talented (N=3)	1	0	2	1	1	1	0	1	2

Student Attitude

With these thoughts in mind, student attitudes were considered to determine if interpretations of the student normalized gain had any validity. In the Spring of 2015, preliminary student interviews were conducted with students (N=8, ages 15-18). These students were in my Learning Academy and were randomly assigned to me at the beginning of the year by the school counselor. From these interviews conducted for the purpose of this classroom research project, I learned that my struggling writers loathe technical writing (Appendix I). Twelve percent of the respondents (N=1) ranked technical writing as an eight or nine on a Likert scale of 1 to 10 where 1 meant they hated writing

and 10 meant they loved writing. Fifty percent (N=4) ranked technical writing as a six or seven. 38% of respondents (N=3) ranked technical writing as a four or five. After looking over my student responses, it was found that all student writers struggled with preparedness and planning, getting a paper ready for submission, and revising a submitted paper.

The following patterns concerning my struggling writers' level of preparedness and planning before they started a writing assignment were also discovered. Fifty percent of the respondents (N=4) did no planning at all. They simply started writing about the topic presented. Twelve percent of the respondents (N=1) did some brainstorming. Upon further probing, it was found that they meant they listed some ideas, but there was no formal organization to their planning. 38% of the respondents (N=3) did some type of outline or webbing before they began to write. Preparedness and pre-planning (regardless of the organizational tools used) is important in a science classroom. Without formal organization, it is difficult for students to support their scientific argument with evidence and draw conclusions based on their data.

From initial student interviews, it was found that struggling writers also lacked the ability or the desire to proofread their papers before submitting them. Twelve percent of students (N=1) did nothing to make sure they had the best paper written. After laughing out loud, one student stated he "*did nothing except for checking for spelling and grammar mistakes.*" 87% of students (N=7) looked back to make sure all conventions (grammar and spelling) were correct. 25% of all students (N=2) suggested they had a

teacher look at their work. Others (50% of the population, N=4) said they used peer editing. Several students interviewed suggested using a peer as a “*second set of eyes.*”

Another troubling finding from the preliminary student interviews was students’ misunderstanding of revision in the writing process. When asked what strategies they used when given the chance to revise their work, twelve percent (N=1) said they used no strategies. By his tone, it was believed he meant he never turned in a revision. 25% of students (N=2) said that they edited places recommended by the teacher or they considered the opinions of the reviewer in their revision process. 25% of students (N=2) said they asked questions of their teacher or reviewer. 38% (N=3) said they corrected incorrect conventions. One student said that she had a “*friend check my work, words, spelling, and the way things sounded. I have them do this at least twice.*” No students mentioned a modification of ideas or content in their writing. From the writing assignments that students have submitted in the past, this has been found to be the norm. Students corrected conventions and grammar. However, very few students corrected their scientific content or thinking. This may be due to student misunderstanding about the nature of the writing that is done in science. Many students think that the CATs done in class are strictly their opinion and not supposed to be based on the content they are learning in class. This deficiency needed to be corrected if students were to increase their understanding of content, scientific reasoning, and higher level thinking skills. With this preliminary information in mind, the two treatment units were planned in hopes to change my students’ attitudes about technical writing as well as improve their scientific comprehension.

To evaluate changes in student attitudes, a Likert survey was administered (Appendices D-F) at the end of each unit following their unit posttest. A total of three Likert surveys were administered. All students were asked to complete the Likert survey. The ratings for the survey ranged from 1-5 where 1 was strongly agree and 5 was strongly disagree. Surveys were numbered in order to ensure all students completed the survey, but still allowed for anonymity in answers. Survey questions were written to gain insight into students' thoughts about writing, their planning and writing process, their revision process, and how they express their ideas about science in writing. Student responses were then grouped into the following categories: attitude about technical writing (questions 1-5), planning and the writing process (questions 6, 7, 9, and 14), peer editing and revision (questions 8, 10, 11, 12, and 13), and idea expression (questions 15, 16, 17, and 18). (*Note: Appendix J shows a summary of all the student responses at the end of the pre-treatment, Self-Directed Inquiry, and Calibrated Peer Review units.*)

To gain further insight, responses were classified and compacted. This technique provided a better understanding of the patterns in student attitudes, which are shown in Appendix K. Statistical significance of student responses was calculated using a chi square analysis. Responses were first grouped by treatment and compared to each other and the pre-treatment responses. No statistical significance was found between the treatment groups and the comparison group when comparing pretreatment responses to Self-Directed Inquiry responses ($p=0.2725$). According to the open-ended responses on the Likert survey, students preferred using the more traditional approach to writing than Self-Directed Inquiry. Likewise, when comparing pretreatment responses to Calibrated

Peer Review responses, no statistical significance was found ($p=0.7191$). As seen in Figure 3, student responses indicated that they preferred the comparison unit and the unit taught using Calibrated Peer Review equally well. More students agreed with the statements on the surveys than disagreed or had no opinion. However, approximately the same number of students indicated they either had no opinion or disagreed with the statements on the surveys than agreed with those statements when evaluating the unit taught using Self-Directed Inquiry. Students also responded to several open-ended questions. According to the open-ended student responses, they preferred the Calibrated Peer Review approach to writing rather than Self-Directed Inquiry or the comparison unit.

Since no statistical significance was found between student responses, then strongly agree and agree responses were combined. Strongly disagree and disagree responses were also combined. A summary of those combined responses is shown in Appendix L. The reasoning for this analysis was because high school students have a problem distinguishing between a strongly felt response and a response. When compressed student responses were compared using Pearson's Chi-squared test, there was a significant difference among student responses. When the pretreatment group was compared to the Self-Directed Inquiry unit, there was a statistically significant difference in responses ($p=0.01745$). There was also a statistically significant difference ($p=0.01745$) when the pretreatment group was compared to the Calibrated Peer Review unit.

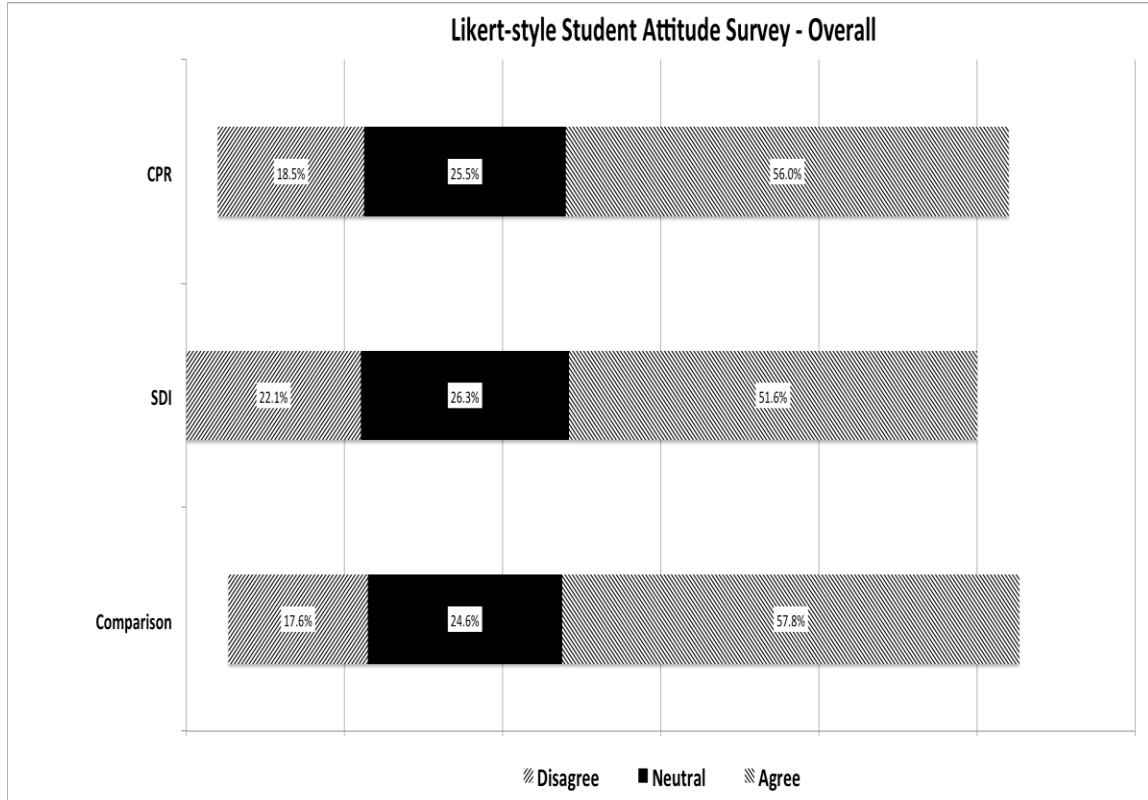


Figure 3. Results showing a comparison of the overall responses to the Likert-style Attitude Survey between treatment and non-treatment groups, ($N=49$).

Students also responded to several open-ended questions. When asked open-ended questions, students preferred using the CPR approach to writing, followed by a more prose-like form of writing, and lastly the Self-Directed Inquiry approach to writing. These findings were especially troubling as recent research had shown Self-Directed Inquiry lead to particularly high gains in student comprehension as well as increased scientific reasoning. The student focus group ($N=6$) was interviewed to determine student mindset. The responses were very enlightening. Several students ($N=3$) explained that they were very confused about the expectations and content in the Self-Directed Inquiry unit. They also thought that the writing assignments during this part of the study were long and many failed to complete them.

When asked about the Calibrated Peer Review unit, all student focus group respondents expressed that they enjoyed using this method. They felt that it was clear and liked the concise method of writing. It, in their opinion, was more manageable with their schedules. They also liked the ability to share their newfound knowledge with their peers and receive their input. As one respondent explained, “if my friends can’t understand what I wrote, then I need to revise to explain myself better.” Another explained that getting written and verbal critiques from their peer reviewer allowed them to fill in details that they assumed everyone knew, but apparently did not.

Survey data was further analyzed by disaggregating by age, gender, and speciality. Figure 4 (see next page) compares student responses by age, in which students are compared as seniors (N=7), juniors (N=14), sophomores (N=13), and freshmen (N=15). Based on their responses, seniors (N=7) indicated that they preferred the comparison unit to the Calibrated Peer Review (CPR) unit. They liked the Self-Directed Inquiry (SDI) unit the least (see Appendix L for a Table of Response Frequency). This class is experienced enough to appreciate the nuances of scientific studies evaluated in the Calibrated Peer Review unit. They have more experience in the lab and realize they need to consider how professionals are collecting data to better improve their own data collection and analysis skills. Juniors (N=14) preferred the Self-Directed Inquiry unit, followed by the comparison unit, then the Calibrated Peer Review unit. This had always been a very curious class and has always preferred learning in the lab, instead of a more traditional approach. Sophomores (N=13) preferred the Calibrated Peer Review unit. They preferred learning using Self-Directed Inquiry next and lastly learning with a more

traditional method used in the comparison unit. This class always rises to any challenge put to them. They are a very laid-back group and aim to please. Finally, freshmen (N=15) also preferred learning using the Calibrated Peer Review method. They preferred learning using more traditional methods than using Self-Directed Inquiry. This is in line with teacher observations. The freshmen class had not had as much lab experience than the older classes. They struggled with science in general.

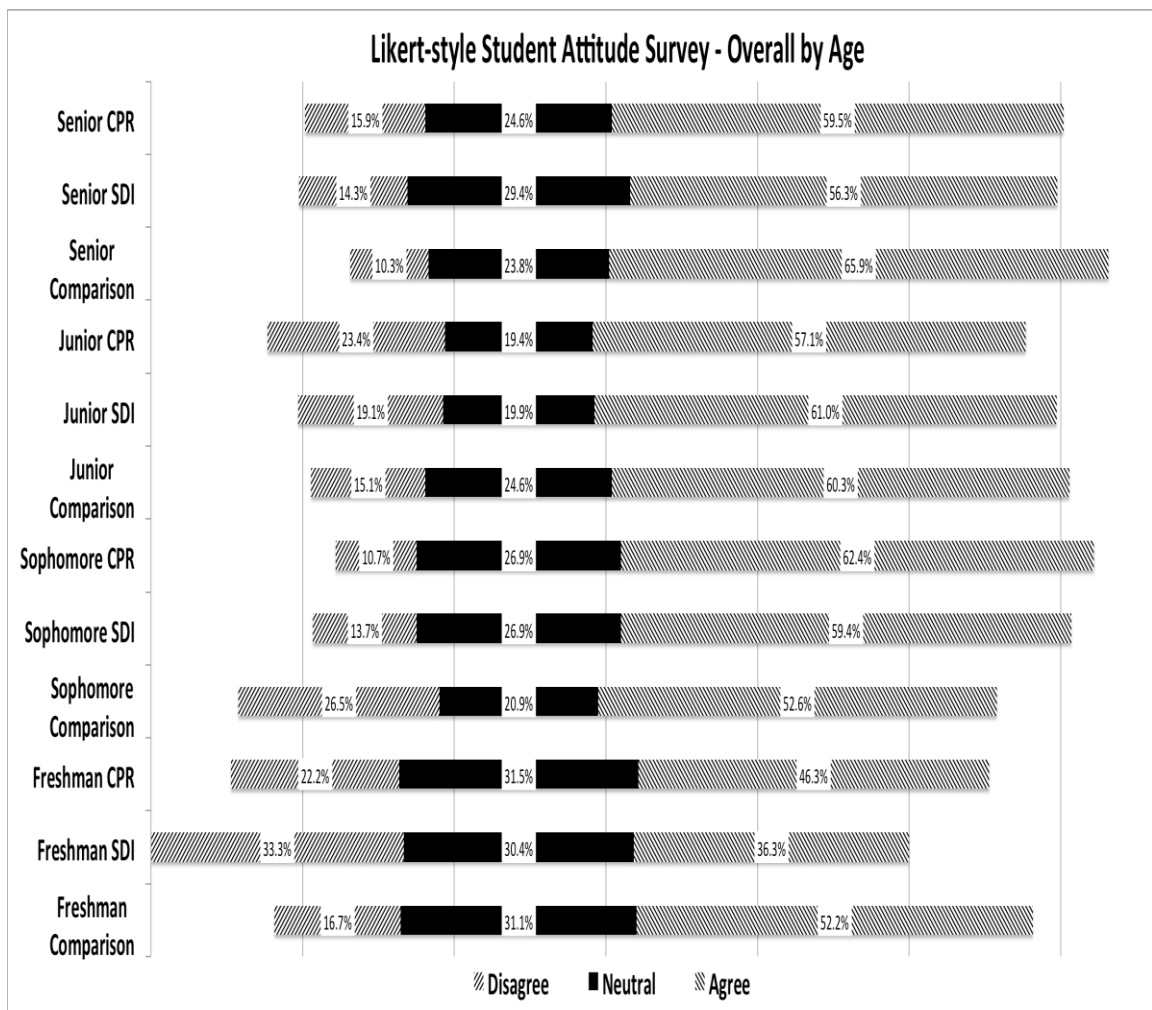


Figure 4. Results showing a comparison of the responses to the Likert-style Attitude Survey by age between treatment and non-treatment groups, (N=49).

Student responses were also compared by gender (see Appendix L for a Table of Response Frequency). Figure 5 compares both male (N=23) and female (N=26) responses by treatment and non-treatment groups. Males tended to preferred the Calibrated Peer Review (CPR) unit, followed by the Self-Directed Inquiry (SDI) unit, and finally the comparison unit. Females preferred the comparison unit to the Calibrated Peer Review (CPR) unit. They liked the Self-Directed Inquiry (SDI) unit the least.

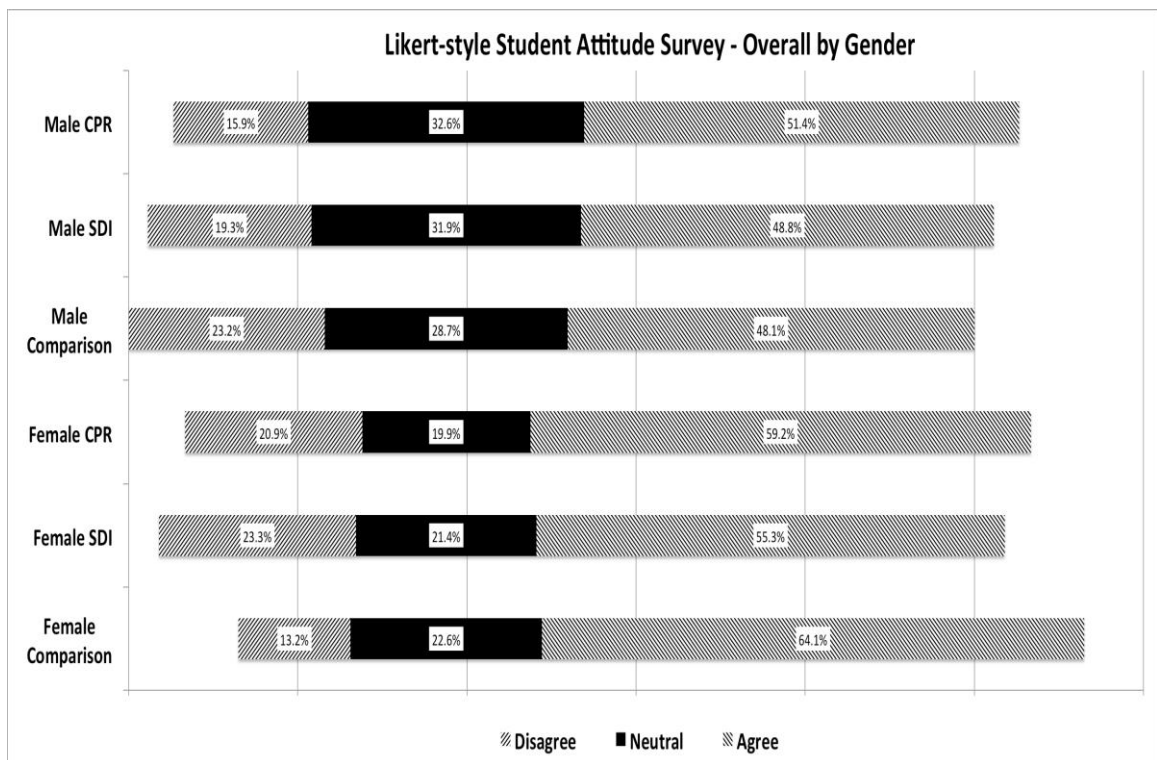


Figure 5. Results showing a comparison of the responses to the Likert-style Attitude Survey by gender between treatment and non-treatment groups, (N=49).

Finally, student responses were compared by speciality. Students were disaggregated into three groups: regular education, students with a learning disability, and students that were gifted or talented (see Appendix L for a Table of Response Frequency). Figure 6 (see next page) shows a diverging stacked bar chart of their responses. Gifted and talented students (N=3) preferred the Self-Directed Inquiry (SDI)

unit, followed by the Calibrated Peer Review (CPR) unit, and finally the more traditional comparison unit. Students with a learning disability (N=6) were more apathetic in their responses. However, they had more positive responses to the Calibrated Peer Review (CPR) unit, followed by an equal preference for the Self-Directed Inquiry (SDI) unit, and

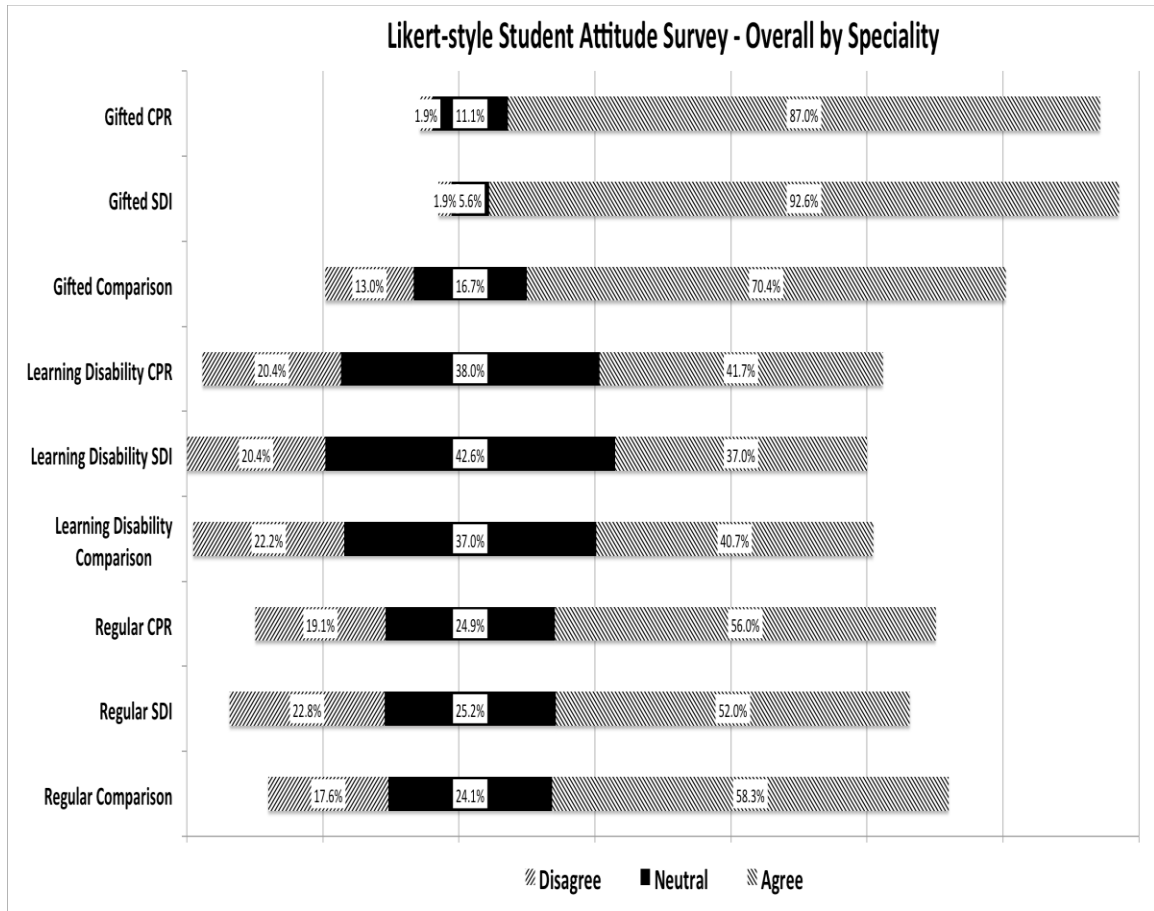


Figure 6. Results showing a comparison of the responses to the Likert-style Attitude Survey by speciality between treatment and non-treatment groups, (N=49).

comparison unit. These students read at a much lower reading level than their peers and struggled with all of the writing prompts. The curriculum was adapted to meet their learning needs based on recommendations on their Individualized Education Program (IEP). Throughout the study, students answered several writing prompts to help them summarize the content, allow for checks for understanding, and determine their mastery

of the content. These prompts were evaluated using the Content and Idea Rubric (Appendix A) and a Curriculum-Based Measurement Probe (CBM) (Appendix B). The Content and Idea Rubric proved to be lacking in its ability to provide consistent data to analyze for patterns concerning students' use of task-specific vocabulary. However, the CBM probe was specifically written to compare the use of task-specific vocabulary within a writing sample. The number of correctly used word sequences as well as total words written and number of correctly used task-specific vocabulary were determined to evaluate writing samples. Next, the percentage of task-specific vocabulary used in the writing sample was calculated. This percentage was compared to each student's normalized gain to determine if there were any emerging patterns that could be seen. There was no correlation between percentage of task-specific vocabulary used in the writing sample and student's normalized gain.

INTERPRETATION AND CONCLUSION

This study sought to determine what strategies could best help struggling writers improve their technical writing and scientific comprehension over a nine-week span. The research questions for this study were as follows:

- What strategies can best help struggling writers improve their technical writing over a nine-week time span?
 - How can scaffolding prompts help all writers improve their technical writing?
 - What are the effects of improved technical writing on student's scientific reasoning?

- What are the effects of improved technical writing on the classroom teacher?
 - In what ways do I play a role in my students' ability to organize their thoughts and share them through the written word?
 - How can I improve my practice to aid students in becoming better writers?

Two strategies (Calibrated Peer Review and Self-Directed Inquiry) were compared to a more traditional approach. Additionally, this study wanted to see if the use of the scaffolding prompts used in Calibrated Peer Review and Self-Directed Inquiry would help all writers improve their technical writing. Finally, the effects of improved technical writing on the practice of the classroom teacher were explored. The teacher's role in aiding students' ability to organize their thoughts and share them through the written word was explored. Plus, how the teacher was able to improve her practice and aid her students in becoming better writers was explored.

Technical Writing Strategies

In response to the question on which technical writing strategies improved technical writing and scientific reasoning, it was found that Calibrated Peer Review did have a positive impact on student scientific comprehension. When students used the Calibrated Peer Review method to learn about the primordial Earth, 91.3% of all students showed a medium to high level of improvement (See Figure 2). Based on student responses to the attitude survey, this was a well-liked and appropriate method to use to help students navigate the myriad of peer-reviewed studies that scientists have published to explain the conditions found on an early Earth (See Figure 3). According to open-ended student responses, they enjoyed using Calibrated Peer Review because it had

defined writing parameters, the length of the writing assignment was manageable and fit into their homework schedule, and it allowed them to learn from their peers and receive timely feedback from their peers.

Despite its initial success at the beginning of the unit, the use of Student-Directed Inquiry did not have the positive effects that I had hoped for my students. While most students did see an increase in the posttest scores when compared to pretest scores, the classes saw relatively the same gain in scores in the comparison unit (See Figure 2). Based on student responses to the attitude survey, the Self-Directed Inquiry approach was either their second or third choice in strategies to use (See Figure 3). According to the open-ended student responses, they did not care for the Self-Directed Inquiry approach because the methods they used were too vague, they found the instructions confusing, and the writing assignments, in their opinion, were too long. The SDI unit was taught at a time of the year when many of the students were ill with influenza. Those that were ill missed a week of school and they had a very difficult time making up the labs they had missed in a timely fashion. In addition, the time period in which SDI was taught was too short. According to the research, SDI is best when taught over a nine week to semester period. A longer time period allows students to better process how to write their inquiry lab reports by allowing more time for feedback (both from their peers and instructor) and the ability to make revision.

The Use of Scaffolding Prompts

In response to my question on the use of scaffolding prompts to help all writers improve their technical writing, it was found that using Classroom Assessment

Techniques (CATs) became a very valuable part of the day-to-day assessment of my students' understanding and comprehension. I became very efficient at reading through these writings, evaluating my students' needs based on their responses, and reteaching or redirecting their laboratories as necessary. These CATs also served as scaffolding prompts by helping students organize their thoughts. When it came time to write their end of the unit writing assessments, these writing assessments were more detailed.

Improvement in Practice

In response to my question regarding how improved technical writing would affect the classroom teacher, I found that throughout this classroom study there were many ways in which to improve my practice. For my less experienced classes (particularly the freshmen and sophomores), I modified the Calibrated Peer Review so that students would meet face to face with their reviewers. First, reviewing partners would read through and evaluate each other's abstracts while completing the Calibrated Peer Review rubric. Next, peer reviewers could ask any questions they might have about the study they were reviewing. Finally, reviewers would give an oral two-sentence summary of what they learned from the reviews and the questions. With this feedback in mind, students then revised their abstract, as necessary, before they submitted it to me for a final review. After the final review was submitted, we had a Round Robin sharing session in which each student explained his or her articles in two sentences. This proved to be a very excellent modification of the CPR technique for both classes.

I also learned that older students (juniors and seniors) could evaluate two or three peer-reviewed articles (based on reading level). However, younger students (freshmen

and sophomores) were most successful evaluating only one article. Since the freshman and sophomore classes were larger, each student had a unique article to share. Because of absences, older students only submitted written abstracts that were evaluated anonymously. They did have the Round Robin sharing session. However, it did not go as smoothly as the younger classes due to the fact that each student shared three abstracts. Several students did not complete all three abstracts so the analyses of all of the methods of studying an early Earth were not covered. However, enough was covered so that students had a basic understanding of the many ways that scientists model an early Earth.

While I dearly loved the Self-Directed Inquiry unit and saw its potential in helping increase students' interest and scientific comprehension, this approach was not as effective for the unit in which it was taught. Students learned about the biology, chemistry, and geology of the thermal features of Yellowstone National Park and how applications of the study of these thermal features are used in distinct fields of science. Many students failed to do the required preparation so interpreting the results of the inquiry activities was very difficult for them. Coupled with students' unwillingness to meet outside of class for help and an influenza outbreak at my school, this unit was a struggle for many students. Toward the end of the Self-Directed Inquiry unit, I found that helping students construct a detailed outline of what was expected on the writing assignment helped them write more comprehensive reports.

To determine where the disconnect was with my students during the Self-Directed Inquiry unit, I disaggregated data by age, gender, and speciality. Juniors and sophomores did best with this unit followed by seniors and freshmen. When considering medium to

high normalized gain, 78% of juniors achieved medium to high gain as did 76% of sophomores. Only 57% of the seniors achieved medium to high gain. Although they had the ability to well with SDI, seniors were less motivated and ready for graduation. Freshmen, on the other hand, needed more time to complete the Self-Directed Inquiry Unit. Only 53% of the freshmen achieved medium to high gain. I felt they would have done better if I could have implemented this treatment over the course of fifteen labs. Females did equally well in both treatments and the comparison units. They indicated they would do whatever was asked so they could achieve a high grade. Males, on the other hand, needed extra time in the implementation of SDI. Finally, when students were compared by speciality, it was found that regular education students, students with a learning disability, and gifted/talented students all had the same percent of medium to high gain (between 67-68% gain).

VALUE

At the end of this classroom study, my students and I found that using Calibrated Peer Review (CPR) as a method of summarizing and evaluating professionally written papers was quite helpful in increasing student comprehension. It also gave students a technical writing strategy that helped them explain the methods used by scientists to model the world around them. CPR proved to be a very versatile method that could be used as a stand-alone strategy that one could use with students to teach an entire unit or a writing strategy incorporated into a daily lesson in which students read about a study related to a topic that they were learning in class.

Most of my frustration during this study came from the Self-Directed Inquiry (SDI) unit. A valid question to consider is what is the best time frame in which to incorporate the use of SDI. The Self-Directed Inquiry treatment was introduced at a time when there were a lot of student absences due to illness and some school activities. I initially thought that students would learn better using Self-Directed Inquiry. I chose it because of the absenteeism that we see after every Christmas break due to illness because I thought that students would be able to work at their own pace and make up the work more easily if they were gone from school. Students struggled with the freedom they were given and were not as experienced, as they should have been in interpreting the results and planning subsequent experiments based on their findings. They did not have the background knowledge from which to pull to know where to direct their next set of experiments. Furthermore, many students lacked the mathematical abilities to analyze the data they collected. I would like to explore this teaching strategy further during the first nine weeks of school next year with my incoming freshmen. Continuing this portion of my action research would be very beneficial because I will have these students for their entire high school career. If I can successfully teach them how to learn using inquiry more effectively, they will be able to use those skills in the rest of their science courses. I will also be able to share my findings with the middle school and Agricultural Education instructors in my district. They will be able to incorporate my findings into their own classes, if they wish. I learned to let the scientific results speak for themselves, instead of just giving students a quick answer. I also learned how to aid my students in determining where they needed to gain more information and how to help my students find age-

appropriate mathematical tools to analyze their data. This was especially true with the freshmen and sophomore classes as they have limited experience with inquiry experiments. At many times, they were completely at a loss and did not have the background to know where they should continue.

Throughout this entire process, I became more reflective within shorter periods of time and more responsive to the individual learning needs of my students. This entire process taught me how to give more meaningful feedback to my students and how to focus on their gain in learning instead of a particular letter grade. As my district moves to a new method of teacher evaluation, these new found skills will be essential as I document my students' improvement in both scientific reasoning and comprehension of fundamental scientific concepts. In addition, since I will be teaching the same students next year, I can continue to work with the freshmen and sophomores in this study to help them develop a manual of protocols that they could use to collect data for their inquiry experiments. Instead of having students complete an entire inquiry unit, sophomores and freshmen will have an inquiry lab based on information they learned within each of their units of study. This method of study should better help them develop the proper background knowledge to help collect more comparable data. Open-ended student responses, student work samples, and observations from my teacher log led me to this conclusion. Students felt very lost in the process to analyze the data they collected. It is very difficult to write about something one does not understand. They need to improve their confidence and methods regarding data collection. With more reliable data and

better methods of analysis, their technical writing should improve because they will have evidence to support their claims.

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APPENDICES

APPENDIX A
CONTENT AND IDEA RUBRIC

CONTENT AND IDEA RUBRIC

Content & Ideas

- ___/ 2.5: Introduction grabs the reader's attention and appropriately introduces the topic
- ___/ 10: Thesis statement makes sense and answers all parts of the prompt
- ___/ 10: All main ideas are clear and focused
- ___/ 10: All main ideas are correct in their assertion or interpretation
- ___/ 10: All main ideas work to support and reinforce the thesis statement
- ___/ 5: All direct evidence (research or quotes from the reading) is explained and contextualized
- ___/ 5: Conclusion restates the thesis in a new way and reviews main points
- ___/ 2.5: Conclusion sums up the paper and gives a sense of finality

Section Total: _____/ 55

Organization

- ___/ 10: Paragraphs are clearly divided by content
- ___/ 5: Writing has a strong & clear beginning, middle and end
- ___/ 5: Each paragraph transitions smoothly into the next
- ___/ 5: Ideas fit together, flow naturally, and build upon each other

Section Total: _____/ 25

Vocabulary & Word Choice

- ___/ 3: All words are used in their correct context
- ___/ 10: Language is appropriate for the task at hand
- ___/ 10: Language is appropriate for the intended audience
- ___/ 5: Author uses task/domain specific vocabulary correctly to enhance writing
- ___/ 2: Words and phrases do not excessively repeat
- ___/ 5: Word choice makes the essay easy and enjoyable to read

Section Total: _____/ 35

Voice & Style

- ___/ 5: Author writes with a distinct voice/point of view
- ___/ 10: Author successfully adapts their voice to the specific task at hand
- ___/ 15: The author adds commentary that successfully explains and contextualizes evidence in their own words

Section Total: _____/ 30

Sentence Fluency

- ___/ 3: Author uses a variety of sentence structures throughout the piece of writing
- ___/ 5: All sentences are complete and clear
- ___/ 2: Sentence beginnings vary throughout the writing
- ___/ 5: Sentences flow smoothly and fit together
- ___/ 10: Transitions are successful and natural

Section Total: _____/ 25

Conventions

- ___/ 5: No spelling errors
- ___/ 5: Punctuation is used appropriately and correctly
- ___/ 5: Sentences have consistent subject-verb agreement
- ___/ 5: All words and phrases are capitalized correctly

Section Total: _____/ 20

Citations & Evidence

- ___/ 5: Evidence used is appropriate and the best fit for each main idea
- ___/ 5: Evidence is appropriately paraphrased or quoted
- ___/ 5: Citations are in the correct format
- ___/ 5: Every piece of evidence has a corresponding citation
- ___/ 5: Words cited page follows paper and is formatted correctly
- ___/ 5: Every main idea has a piece of evidence for support

Section Total: _____/ 30

APPENDIX B

CURRICULUM-BASED MEASUREMENT (CBM) PROBE

CURRICULUM-BASED MEASUREMENT (CBM) PROBE

A. Total words in writing passage _____

B. Total correctly spelled words in passage _____

C. Total task/domain specific words in passage _____

D. Total correct writing sequences in passage _____

Percent of task/domain specific vocabulary per passage _____
(C/A * 100%)

APPENDIX C
CALIBRATED PEER REVIEW RUBRIC

CALIBRATED PEER REVIEW RUBRIC

Directions: When evaluating an abstract, use the entire scale from 1-10 to rate the abstract. If an abstract does not match the guidelines completely, choose the rating that best describes the abstract as a whole. If an abstract contains convention errors that make it difficult to understand, you should rate the abstract one point lower than you would have otherwise.

Guideline	10	9	8	7	6	5	4	3	2	1
Abstract demonstrates a complete understanding of main concepts. All main points are correct.										
No unnecessary statements are made. Summary is brief.										
All guiding questions are answered.										
Abstract is organized and easy to follow.										
Abstract contains no spelling or grammatical errors.										
Abstract is written with the correct voice.										

Who:

What:

Where:

When:

Why:

How:

Recommendations below are from <http://serc.carleton.edu/resources/14183.html>.

1 or 2- The essay is completely unsatisfactory. The essay does not demonstrate an understanding of the concepts, and major points are incorrect. The essay does not address or barely addresses the guiding questions and the writing prompt. The essay is disorganized and difficult to follow.

3 or 4- The essay demonstrates only a vague understanding of the concepts involved. The essay does not fully explain the main ideas, lacks clear organization, and may make some incorrect statements. The essay weakly addresses the guiding questions and the writing prompt, making vague and minor points.

5 or 6- The essay is acceptable but does not demonstrate a sophisticated understanding of the concepts. The essay makes some good points but may contain a few incorrect and/or irrelevant statements. The essay addresses most of the guiding questions and the writing prompt, explaining most of the main ideas. The essay has some organization but could be presented more clearly and/or more succinctly.

7 or 8- The essay is a good quality effort. The essay demonstrates an understanding of the principles and does not make any incorrect statements, though a few may be irrelevant. The essay addresses all of the guiding questions and the writing prompt, explaining all the main ideas but a few details may be unnecessary or vague. The essay is mostly clear and well-organized.

9 or 10- The essay excels in all areas. A sophisticated understanding of the concepts is demonstrated without unnecessary or incorrect statements. The essay addresses all of the guiding questions and the writing prompt, explaining all the ideas correctly and succinctly. The essay is well organized and clearly presented. In addition to all of these qualities, a “10” essay must have no grammatical or spelling errors.

APPENDIX D

PRE-TREATMENT LIKERT-STYLE SURVEY

PRE-TREATMENT LIKERT-STYLE SURVEY

1-strongly agree 2-agree 3-neutral 4-disagree 5-strongly disagree

1. I enjoy writing scientific papers.

1 2 3 4 5

Why did you answer the way you did in the last question?

2. I feel that I am a good scientific writer.

1 2 3 4 5

3. It is worthwhile taking time to express my thoughts through writing.

1 2 3 4 5

Why did you answer the way you did in the last question?

4. If I can write about something, I can understand it better.

1 2 3 4 5

Can you give me an example?

5. Other people are able to read my writing and understand it.

1 2 3 4 5

6. It is worthwhile to take extra time to proofread my work.

1 2 3 4 5

Please explain your answer to the last question.

7. I take advantage of the writing tools to help me be a better writer.

1 2 3 4 5

Can you give me an example?

8. I take advantage of help from my classmates when editing my work.

1 2 3 4 5

9. I make an outline before I write an assignment.

1 2 3 4 5

10. I revise my work to correct for mistakes in grammar and conventions.

1 2 3 4 5

11. My teacher is the best editor of my writing.

1 2 3 4 5

12. My teacher provides me with enough feedback to improve my writing.

1 2 3 4 5

Why did you answer the way you did in the last question?

13. When revising, I consider the revision of my ideas as important as correcting mistakes in spelling and grammar.

1 2 3 4 5

14. I ask what is required to complete an organized lab report.

1 2 3 4 5

15. I have the freedom I need to express my thoughts about the experiments done in class.

1 2 3 4 5

16. My current way of writing works for me.

1 2 3 4 5

Why did you answer the way you did in the last question?

17. I could improve my writing.

1 2 3 4 5

18. I understand the issues related to the experiments done in class.

1 2 3 4 5

APPENDIX E

POST TREATMENT LIKERT-STYLE SURVEY (SELF-DIRECTED INQUIRY)

POST TREATMENT LIKERT-STYLE SURVEY (SELF-DIRECTED INQUIRY)

1-strongly agree 2-agree 3-neutral 4-disagree 5-strongly disagree

1. I enjoy writing scientific papers.

1 2 3 4 5

Why did you answer the way you did in the last question?

2. I feel that I am a good scientific writer.

1 2 3 4 5

3. It is worthwhile taking time to express my thoughts through writing.

1 2 3 4 5

Why did you answer the way you did in the last question?

4. If I can write about something, I can understand it better.

1 2 3 4 5

Can you give me an example?

5. Other people are able to read my writing and understand it.

1 2 3 4 5

6. It is worthwhile to take extra time to proofread my work.

1 2 3 4 5

Please explain your answer to the last question.

7. I take advantage of the writing tools to help me be a better writer.

1 2 3 4 5

Can you give me an example?

8. I take advantage of help from my classmates when editing my work.

1 2 3 4 5

9. I make an outline before I write an assignment.

1 2 3 4 5

10. I revise my work to correct for mistakes in grammar and conventions.

1 2 3 4 5

11. My teacher is the best editor of my writing.

1 2 3 4 5

12. My teacher provides me with enough feedback to improve my writing.

1 2 3 4 5

Why did you answer the way you did in the last question?

13. When revising, I consider the revision of my ideas as important as correcting mistakes in spelling and grammar.

1 2 3 4 5

14. I ask what is required to complete an organized lab report.

1 2 3 4 5

15. I have the freedom I need to express my thoughts about the experiments done in class.

1 2 3 4 5

16. My current way of writing works for me.

1 2 3 4 5

Why did you answer the way you did in the last question?

17. I could improve my writing.

1 2 3 4 5

18. I understand the issues related to the experiments done in class.

1 2 3 4 5

APPENDIX F

POST TREATMENT LIKERT-STYLE SURVEY (CALIBRATED PEER REVIEW)

POST TREATMENT LIKERT-STYLE SURVEY (CALIBRATED PEER REVIEW)

1-strongly agree 2-agree 3-neutral 4-disagree 5-strongly disagree

1. I enjoy writing scientific papers.

1 2 3 4 5

Why did you answer the way you did in the last question?

2. I feel that I am a good scientific writer.

1 2 3 4 5

3. It is worthwhile taking time to express my thoughts through writing.

1 2 3 4 5

Why did you answer the way you did in the last question?

4. If I can write about something, I can understand it better.

1 2 3 4 5

Can you give me an example?

5. Other people are able to read my writing and understand it.

1 2 3 4 5

6. It is worthwhile to take extra time to proofread my work.

1 2 3 4 5

Please explain your answer to the last question.

7. I take advantage of the writing tools to help me be a better writer.

1 2 3 4 5

Can you give me an example?

8. I take advantage of help from my classmates when editing my work.

1 2 3 4 5

9. I make an outline before I write an assignment.

1 2 3 4 5

10. I revise my work to correct for mistakes in grammar and conventions.

1 2 3 4 5

11. My teacher is the best editor of my writing.

1 2 3 4 5

12. My teacher provides me with enough feedback to improve my writing.

1 2 3 4 5

Why did you answer the way you did in the last question?

13. When revising, I consider the revision of my ideas as important as correcting mistakes in spelling and grammar.

1 2 3 4 5

14. I ask what is required to complete an organized lab report.

1 2 3 4 5

15. I have the freedom I need to express my thoughts about the experiments done in class.

1 2 3 4 5

16. My current way of writing works for me.

1 2 3 4 5

Why did you answer the way you did in the last question?

17. I could improve my writing.

1 2 3 4 5

18. I understand the issues related to the experiments done in class.

1 2 3 4 5

APPENDIX G
STUDENT FOCUS GROUP QUESTIONS

STUDENT FOCUS GROUP QUESTIONS

- 1) What is your favorite thing about school?
- 2) On a scale of one to ten, how well do you like writing? When did you first realize that?
- 3) When you get a topic about which to write in science class, what is first thing that you do to prepare for writing?
 - a) ...and then what do you do? (Do you do any pre-planning or do you just jump and get started?) Can you give an example?
- 4) How well does that strategy work out for you?
- 5) If you get writer's block, what are some things you do to overcome writer's block.
 - a) Do you have some specific strategies (or tricks) that help you overcome writer's block?
- 6) Once you finish your writing, is there anything you do to make sure it is complete and ready to submit? Where did you learn that?
- 7) If you are given a chance to revise it, what are some strategies you use to make your writing better?
- 8) Is there anything else you would like to share with me?

APPENDIX H
IRB EXEMPTION



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
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MEMORANDUM

TO: Ruth Hutson and Walter Woolbaugh
FROM: Mark Quinn, Chair *Mark Quinn CJ*
DATE: December 1, 2015
RE: "Which Technical Writing Strategy Improves Student Writing and Comprehension?" [RH120115-EX]

The above research, described in your submission of December 1, 2015, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX I

PRE-STUDY LIKERT-STYLE SURVEY

PRE-STUDY LIKERT-STYLE SURVEY

1-strongly agree 2-agree 3-neutral 4-disagree 5-strongly disagree

1. I enjoy writing scientific papers.

1 2 3 4 5

2. I feel that I am a good scientific writer.

1 2 3 4 5

3. If I can write about something, I can understand it better.

1 2 3 4 5

4. Other people are able to read my writing and understand it.

1 2 3 4 5

5. It is worthwhile to take extra time to proofread my work.

1 2 3 4 5

6. I take advantage of help from my classmates when editing my work.

1 2 3 4 5

7. I make an outline before I write an assignment.

1 2 3 4 5

8. My teacher is the best editor of my writing.

1 2 3 4 5

9. When revising, I consider the revision of my ideas as important as correcting mistakes in spelling and grammar.

1 2 3 4 5

APPENDIX J
LIKERT-STYLE SURVEY RESPONSES

LIKERT-STYLE SURVEY RESPONSES

Pre-treatment Unit		Survey Ratings				
Question Number	Question	5	4	3	2	1
1	I enjoy writing scientific papers.	8	20	18	2	1
2	I feel that I am a good scientific writer.	3	14	15	17	0
3	It is worthwhile taking time to express my thoughts through writing.	1	10	13	18	7
4	If I can write about something, I can understand it better.	2	7	16	16	8
5	Other people are able to read my writing and understand it.	0	7	16	17	9
6	It is worthwhile to take extra time to proofread my work.	4	0	8	19	18
7	I take advantage of the writing tools to help me be a better writer.	3	5	20	13	8
8	I take advantage of help from my classmates when editing my work.	3	4	13	19	10
9	I make an outline before I write an assignment.	2	10	13	19	4
10	I revise my work to correct for mistakes in grammar and conventions.	5	3	6	9	26
11	My teacher is the best editor of my writing.	2	4	5	15	23
12	My teacher provides me with enough feedback to improve my writing.	2	2	5	19	21
13	When revising, I consider the revision of my ideas as important as correcting mistakes in spelling and grammar.	2	4	15	17	11
14	I ask what is required to complete an organized lab report.	3	4	9	24	9
15	I have the freedom I need to express my thoughts about the experiments done in class.	1	4	13	22	9
16	My current way of writing works for me.	3	3	15	17	11
17	I could improve my writing.	3	2	5	15	24
18	I understand the issues related to the experiments done in class.	3	2	12	21	11

Note: 5-strongly disagree, 4-disagree, 3-neutral, 2-agree, 1-strongly agree

Self-Directed Inquiry Unit

Question Number	Question	Survey Ratings				
		5	4	3	2	1
1	I enjoy writing scientific papers.	13	14	18	3	0
2	I feel that I am a good scientific writer.	4	12	19	12	1
3	It is worthwhile taking time to express my thoughts through writing.	2	5	15	19	7
4	If I can write about something, I can understand it better.	3	7	15	17	6
5	Other people are able to read my writing and understand it.	4	6	19	14	5
6	It is worthwhile to take extra time to proofread my work.	4	4	8	14	18
7	I take advantage of the writing tools to help me be a better writer.	2	8	17	13	8
8	I take advantage of help from my classmates when editing my work.	3	9	11	19	6
9	I make an outline before I write an assignment.	2	8	15	19	4
10	I revise my work to correct for mistakes in grammar and conventions.	4	7	6	19	12
11	My teacher is the best editor of my writing.	6	3	9	12	18
12	My teacher provides me with enough feedback to improve my writing.	4	4	9	19	12
13	When revising, I consider the revision of my ideas as important as correcting mistakes in spelling and grammar.	2	6	10	17	13
14	I ask what is required to complete an organized lab report.	4	4	10	18	12
15	I have the freedom I need to express my thoughts about the experiments done in class.	4	7	12	17	8
16	My current way of writing works for me.	3	7	16	16	6
17	I could improve my writing.	6	2	4	15	21
18	I understand the issues related to the experiments done in class.	4	7	12	15	10

Note: 5-strongly disagree, 4-disagree, 3-neutral, 2-agree, 1-strongly agree

Calibrated Peer Review Unit

Question Number	Question	Survey Ratings				
		5	4	3	2	1
1	I enjoy writing scientific papers.	6	12	20	7	4
2	I feel that I am a good scientific writer.	4	10	20	14	1
3	It is worthwhile taking time to express my thoughts through writing.	3	6	14	16	10
4	If I can write about something, I can understand it better.	3	8	16	15	7
5	Other people are able to read my writing and understand it.	1	5	16	20	7
6	It is worthwhile to take extra time to proofread my work.	2	7	5	21	14
7	I take advantage of the writing tools to help me be a better writer.	2	8	12	19	8
8	I take advantage of help from my classmates when editing my work.	3	7	12	21	6
9	I make an outline before I write an assignment.	2	7	21	13	6
10	I revise my work to correct for mistakes in grammar and conventions.	3	7	8	21	10
11	My teacher is the best editor of my writing.	5	3	13	9	19
12	My teacher provides me with enough feedback to improve my writing.	3	3	7	19	17
13	When revising, I consider the revision of my ideas as important as correcting mistakes in spelling and grammar.	1	5	13	15	15
14	I ask what is required to complete an organized lab report.	4	2	9	22	12
15	I have the freedom I need to express my thoughts about the experiments done in class.	3	4	12	19	11
16	My current way of writing works for me.	1	4	13	25	6
17	I could improve my writing.	4	2	5	14	24
18	I understand the issues related to the experiments done in class.	6	7	9	18	9

Note: 5-strongly disagree, 4-disagree, 3-neutral, 2-agree, 1-strongly agree

APPENDIX K

LIKERT-STYLE STUDENT RESPONSES BASED ON CATEGORY

LIKERT-STYLE STUDENT RESPONSES BASED ON CATEGORY

Pre-treatment Unit

Category	Survey Ratings				
	5	4	3	2	1
Thoughts about writing	14	58	78	70	25
The planning and writing process	12	19	54	70	40
The revision process	14	17	40	84	90
Idea expression	10	11	45	75	55

Self-Directed Inquiry Unit

Category	Survey Ratings				
	5	4	3	2	1
Thoughts about writing	26	45	89	65	20
The planning and writing process	11	29	53	67	36
The revision process	20	24	45	88	68
Idea expression	17	23	45	65	46

Calibrated Peer Review Unit

Category	Survey Ratings				
	5	4	3	2	1
Thoughts about writing	17	41	86	72	29
The planning and writing process	9	29	50	74	34
The revision process	16	20	50	86	73
Idea expression	14	17	39	76	50

Note: 5-strongly disagree, 4-disagree, 3-neutral, 2-agree, 1-strongly agree

APPENDIX L

COMPRESSED STUDENT RESPONSES BASED ON CATEGORY

COMPRESSED STUDENT RESPONSES BASED ON CATEGORY

Pre-treatment Unit

Category	Survey Ratings		
	4/5	3	1/2
Thoughts about writing	72	78	95
The planning and writing process	31	54	110
The revision process	31	40	174
Idea expression	21	45	130

Self-Directed Inquiry Unit

Category	Survey Ratings		
	4/5	3	1/2
Thoughts about writing	71	89	85
The planning and writing process	40	53	103
The revision process	44	45	156
Idea expression	40	45	111

Calibrated Peer Review Unit

Category	Survey Ratings		
	4/5	3	1/2
Thoughts about writing	58	86	101
The planning and writing process	38	50	108
The revision process	36	50	159
Idea expression	31	39	126

Note: 5-strongly disagree, 4-disagree, 3-neutral, 2-agree, 1-strongly agree