

EFFECTS OF FOCUSED LITERACY TECHNIQUES ON SCIENTIFIC WRITING
SKILLS IN THE CHEMISTRY CLASSROOM

by

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ABSTRACT

The Common Core State Standards and Next Generation Science Standards have shifted demand towards literacy excellence. This project was designed to determine if dedicating a set amount of time each week to teaching and practicing literacy skills in a Chemistry classroom would increase student's scientific writing ability. Specifically, would students be better able to communicate scientific information using evidence, data, and content specific vocabulary terms. Formative assessments, peer reviewing, and discussion strategies were utilized over a six week period. The results indicate that these strategies are effective in increasing the writing ability of students in a science classroom. Additionally, students indicated a positive value of learning writing skills in a science classroom.

INTRODUCTION AND BACKGROUND

There are approximately 900 students at South Burlington High School, a public school in a suburb of the most populated town in northern Vermont. Partially lying along Lake Champlain, the town of only 16.49 square miles is home to over 8,429 households and Vermont's largest international airport. The median family income was \$64,756 and median income per capita was \$37,425 according to the 2010 census (US Census Bureau). Not only is the town considered one of the best places to raise a family, but the school system is ranked as the top public school in the state according to Business Insider (Martin, 2015).

The town is also home to a large number of refugee families from Sudan, Nepal, Bhutan, Tibet, India, and various other countries facing extreme living conditions. This diversity is welcome in the community, as Vermont is one of the least diverse states in the nation. As our school has become more diverse, awareness and learning opportunities have become available to students, such as an international food day, service trips to developing countries, and an international exchange program with Japan, France, Spain, and Germany.

Classroom Environment and Problem Statement

I have been teaching chemistry at South Burlington High School for three years. Chemistry is offered at three different levels; Advanced Placement Chemistry, College-Preparatory Chemistry, and a project based course known as 'Matter Matters'. I teach the latter two levels, and the course most students take is College-Preparatory Chemistry. College-Preparatory Chemistry has a loose pre-requisite of having completed Algebra II and being enrolled in pre-Calculus. The pre-requisite is not strictly enforced leading to a

widely heterogeneous mix of students in each class. This mix of abilities, compounds the fact that few students have little training in scientific literacy skills and leads to students who fail to understand information found in scientific texts. They struggle with explaining and defending their own data or findings verbally. In a student's mind, there is a disconnect between science and language classes and they find difficulty transferring skills gained in one class to another.

New educational standards, the Next Generation Science Standards (NGSS), have shifted to focus on this problem. Since the state of Vermont has adopted NGSS, science teachers will now have to integrate literacy techniques to foster student achievement in content standards weighted on successful science literacy skills. Using these standards, the South Burlington High School science department has created five proficiency based graduation requirements, or PBGR's (Table 1).

Table 1
South Burlington High School's Science Proficiency Based Graduation Requirements

Graduation Proficiency	Brief Description
1. Scientific Inquiry	Students will be able to develop questions and hypotheses regarding the physical and living world
2. Investigation	Students will be able to plan and carry out scientific investigations to find answers and/or design solutions to the questions/problems
3. Analysis	Students will be able to analyze and interpret data to develop an explanation or to design solutions to scientific questions/engineering problems
4. Conceptual thinking	Students will be able to use appropriate mathematic and conceptual thinking for scientific reasoning
5. Synthesis of Information	Students will be able to obtain, evaluate, and communicate information about the physical and living world.

In addition to the science PBGR's, our school is in the process of creating five transferrable skills in all content areas that students will need to demonstrate proficiency in order to graduate (Table 2).

Table 2

South Burlington High Schools Transferrable Skills (not yet finalized)

Transferrable Skill	Description
1. Clear and Effective Communication	Students will demonstrate organized, purposeful communication using evidence and logic. They can integrate information from multiple sources using appropriate, content specific language.
2. Self-Direction	Students can identify, manage, and assess opportunities. They can set goals and make informed decisions demonstrating flexibility, responsibility, and learning.
3. Creative and Practice Problem Solving	Students will observe and evaluate situations in order to define problems. They can make predictions, design data and analysis strategies, and synthesize evidence, arguments, and claims.
4. Citizenship	Students can participate and contribute to the enhancement of the community. They can take responsibility for personal decisions and actions.
5. Informed and Integrative Thinking	Students can apply knowledge from various disciplines to real life situations. They can develop and use models from multiple sources to explain phenomena.

The focus of my Action Research (AR) project was directly aligned with the fifth PBGR proficiency, Synthesis of Information, and the first transferrable skill, clear and effective communication. Both the transferrable skill and science PBGR were used as guidelines in assessing student work throughout the project.

Focus Questions

In order to increase student scientific literacy, students dedicated at least 60 minutes per week to focused literacy strategies in the classroom. This exercise aimed to help students better 'understand like a scientist' and increase their metacognition.

Working with the school districts' literacy coach, I learned techniques to teach students

how to better understand scientific texts and data tables. These techniques included using focused questioning techniques specific to academic and content vocabulary, creating anchor charts containing scientific sentences starters and frames, planning group writing and peer editing activities, and using various formative assessments to encourage growth of scientific literacy skills. The goal was that students would leave the course with a better ability to use evidence, defined as both reference sources and personal experimental data, in their written work, and to better understand the scientific work around them. The main question of my Action Research project was: Will the focused use of disciplinary literacy techniques allow chemistry students to demonstrate their understanding of content specific language and data analysis through writing? The following sub-questions were also addressed in my research:

- Will literacy techniques increase student comprehension and use of content specific language?
- How does the focus of literacy in a science classroom increase students' ability to argue with evidence through writing?
- Will they feel their ability to synthesize information and think like a scientist has improved after focusing specifically on scientific literacy?

CONCEPTUAL FRAMEWORK

It is very difficult to understand a topic in a high level course, such as chemistry, where students have not been trained to dig deeper into content, as opposed to reading the text for simple facts. I currently engage with students who fail to understand data heavy texts produced in the scientific community. The problem becomes two-fold when students are then asked to produce their own data and analyze this information. Due to

the lack of fluent interpretation of technical writing, the students struggle with writing technically themselves.

Importance of Scientific Literacy

The importance of literacy has never been contested in education, but with shifts towards scientific careers centered on the demands of our growing world, the importance of literacy in science is ever more important. Van Den Broek and Kendeau (2008) found that “much of learning that takes place in and out of schools is based on successful comprehension of texts” (p. 335) and Myres (2009) points out that literacy “has an impact on an individual’s ability to participate in society and to understand important public issues” (para. 2). Unfortunately, it has been found that high-school graduates are becoming less likely to grasp the information contained in complex texts. This is directly affecting all graduates in terms of success, whether their post high school path leads them to college or the workforce (Bauerlein, 2011).

A challenge of technical writing lies in the fact that students fail to understand complex, technical, scientific texts. If a student is unable to comprehend such writing and terminology, how can we expect that type of language and writing from students? Britt, Richter, & Rouet (2002) describe three qualities of scientific texts that makes reading challenging. The first quality is the complexity of the text. Many scientific texts aim to pack as much information as possible into a short description, which can lead to disinterest or difficulty in understanding. The second quality discussed is the fact that students need to mentally compile information from several sources in order to form “an integrated mental model of the information contained in these documents” (p. 107).

Through the use of concept maps, visual organizers, and questioning techniques, students can help solidify mental connections between texts and better understand the use of vocabulary terms in application. The final quality that Britt, Richter, & Rouet (2002) describe is that the writing style or genre of many scientific texts “presents a challenge for less experienced readers” (p. 108). Genres that are heavily used with students are peer-reviewed papers, literature reviews, or textbooks; all of which are dense with precise facts and specific language aimed at readers with assumed background of the topic. Increasing students’ metacognition in reading and writing ‘like a scientist’ may help train minds throughout the duration of a chemistry course, thus increasing the number of scientifically literate citizens.

Another layer to the complexity of scientific literature is the use of graphics that are embedded throughout text. Graphics, such as data tables, charts, and graphs are used extensively in texts because a lot of information can be packed into a neat, compact figure. Students are not explicitly taught to understand flowcharts, maps, tables, charts, etc. within texts, and the texts themselves do not offer much support in learning how to interpret the figures (McTigue & Flowers, 2011). Emphasis on the ability to understand graphical representations may not be at the forefront of the science curriculums in high-school, but it is on standardized testing. Yeh and McTigue (2009) found that on standardized tests throughout the country, more than half of the questions relied on the use of graphical representations. The focus on visual literacy is just as important as textual in science courses.

Types of Literacy Techniques for Use in Science

It has been shown that simple steps, such as surrounding students with literacy tools can have a profound effect on literacy skills (Neuman and Roskos, 1992). Continual modeling of data tables and graphical representations by teachers helps students use similar devices. Roberts, *et al.*, (2013) lists many techniques that are effective in getting students to read, comprehend, and reiterate many types of graphical representations, such as:

- Reinforcing concepts in text by talking about the graphics imbedded in those texts and vice versa
- Having students create graphics for comparison and discussion with classmates
- Pairing students to read graphics with each other, which encourages support and content-specific discourse

Secondary teachers work in an environment in which they are constrained by block-scheduling and content-specific learning goals. Unfortunately, these constraints lead to teachers that do not focus on solely literacy within their content area (Moje, 2008). However, the approach known as Writing to Learn (WtoL) has been found to be very effective in the sciences. This technique does focus on teaching literacy skills separate from content, but then uses these skills in learning new content. Teachers should recognize the importance of taking the time to teach simple literacy skills in order to give students the tools to learn content. One skill which can increase student engagement with texts above a student's reading level is the ability to "close read". Fisher and Frey (2015) suggest four known methods to teach students how to do this:

- Use short, complex texts – this does not necessarily need to be in the form of a stand-alone text, but can be a combination of highlighted passages that will lead to students building an understanding of the bigger picture
- Foster discourse based activities on simple broad questions – students should engage in discussions regarding vocabulary and the structure of the text
- Encourage text annotation – provide support in learning how to annotate texts because “when students understand that they’re expected to produce evidence from the text to support their responses, they start to take notes about the text” (p. 56)
- Use curiosity sparking texts – deliberately use texts that can encourage debate or deeper questioning, or choose texts that with close reading can be applied to new ideas and concepts

The third suggestion above regarding the use of text annotation to understand evidence can be coupled with peer reviewing to increase student awareness of writing scientific text. Cho and MacArthur (2011) studied whether peer review of writing samples helps increase the reviewers own writing skills. They found that the act of peer reviewing (with training) provides practice of cognitive skills needed for review of one’s own written work and also subjects reviewers to a range of writing quality and skills which can help outline the important factors needed for a high quality response.

METHODOLOGY

Following the Action Research classroom model, three College-Preparatory Chemistry classes were considered the treatment group. Students were aware that

participation in the study was not mandatory and they would not be penalized if they chose to not participate. The research methods utilized received exemption from the South Burlington High School principal and the Montana State University Institutional Review Board.

The students in these three classes were subjected to an increased focus on fostering scientific literacy. Students worked with myself and our district's literacy coach to learn techniques to foster understanding of reading quantitative technical texts and formulating written responses that include quantitative data and high level scientific terminology. Throughout the Action Research period, there was a focus on scientific writing strategies, formative assessment techniques, and focused questioning that encouraged students to understand, discuss, think, and write using the language and techniques they see in scientific texts. The implementation period spanned two chemistry units; gas laws and solutions, which was approximately six weeks of class.

Participants

There were 63 students in the treatment group. Students were in three different classes of College-Preparatory Chemistry. Of the 63 students in these classes, 30 were boys and 33 were girls. Three students were on 504 plans with a diagnosis that require additional academic support, typically in the form of additional time for reading and writing assignments. There were no students on Individualized Education Plans.

At South Burlington High School, there are six sections of College-Preparatory Chemistry. The other three classes, taught by another teacher, were considered the non-treatment, or control group, which provided additional means for comparison. The

control group contained 32 students that were willing to participate in the survey and writing task.

Intervention

Prior to the intervention, all students in the treatment group were given a Likert survey (Appendix A) in which they analyzed their own ability to read and communicate scientific information. Students responded to questions asking whether they felt they were proficient at understanding and communicating written scientific information. The survey was given at the start of the intervention in order to get students thinking about the importance of effective communication. The second pre-treatment data set collected from students were writing samples. Students utilized their own data and graph generated in a lab comparing the relationship between temperature and pressure of a gas to respond to a simple prompt (Appendix B). The goal was be able to generate a conclusion in a clear and concise manner that was supported with data. The writing samples were scored against a checklist generated by two PBGR's (Appendix C) which looked at the use of scientific specific language and data, and evidence based explanations or claims in writing. An example of the pre-treatment writing sample is shown in Figure 1.

1. Using your own data and own generated graph, fully describe the relationship between pressure and temperature.

As the pressure went up the temperature also went up. ~~This~~ My ~~data~~^{graph} shows that it goes up at a constant rate, my calculations prove this because they show ~~it is close to~~ the points are close to the slope represented on the graph. ~~Since~~ The graph's slope represents constant, it shows that ~~as~~ pressure goes up, temperature goes up and therefore they are directly proportional. The calculations done show the data were close to constant, the experiment proves that as temperature rises, pressure also rises.

Figure 1. Pre-treatment writing sample.

After the pre-treatment data collection, the treatment phase began. This consisted of at least sixty minutes a week dedicated to literacy instruction and activities in the science classroom. This time was usually separated into two thirty minute sections, and followed the general schedule below:

1. Look at teacher-selected examples of previous task
2. Teacher-led, whole-class, or small-group discussion about examples
3. Literacy instructional period
4. Practice Task

In the first week of treatment students were asked to look at anonymous examples of the pre-treatment writing samples and analyze what made an excellent versus a poor response. From this, we constructed anchor charts that contained scientific sentence

frames and sentence starters. Students were also challenged to keep track of both academic and content-specific vocabulary in order to build a word wall in the classroom, which was used as reference throughout the treatment phase (Appendix D). After a second writing task, students self-assessed their work based on the checklist (Appendix C) and developed two goals they had for themselves throughout the intervention period. These goals provided me with a way to organize students during partner activities.

In the first few weeks of treatment students worked together to gain writing skills. Students were commonly grouped with a student of differing literacy skills or with students who had identified similar goals. They were asked to produce short written responses using a variety of prompts. An example of a partner response prompt is shown in Figure 2. Responses were submitted via Google Forms and then analyzed by classmates, myself, or both. Once students were comfortable with some basic skills, such as choosing proper academic and content area vocabulary, and selecting the best data to support the claim, we transitioned into individual assignments.

SENTENCE STARTER

Surface tension causes water to form spherical drops because

TERMS

- hydrogen bonds (bonding)
- intermolecular forces
- force of attraction
- surface area

Figure 2. Group response prompt.

At this time there was an increase in student writing with a focus on open-ended or free response, high-order, questioning techniques. These questions, known as tiered questions, require students to synthesize information from multiple data sources including laboratory experiments, text, or demonstrations (Appendix E). Tiered questions involve the student choosing an answer from a list, then providing a written explanation as to why they chose their initial response. The questions were analyzed first on whether they had chosen the correct response to the multiple choice answer, and then whether the written answer contained the scientific language (vocabulary, sentence framing, and completeness) and/or the correct, incorrect, or missing use of scientific evidence. When evaluating for use of scientific evidence, I looked at whether the student cited quantitative data and/or references from other sources (Appendix F). I analyzed the first two sets of tiered questions and typed up student examples. These examples became the basis for discussion during the next literacy day. The last tiered question was collected and

redistributed for annotation. Students were prompted to analyze the response and provide constructive feedback, similar to what they had been receiving throughout the treatment phase (Appendix G). An example of a peer-reviewed annotation is shown in Figure 3. In the annotations, students were asked to underline any sentence starter or frame, circle content-specific language, box academic language, cross off incorrect or unneeded words and statements, and then provide constructive feedback to their classmate.

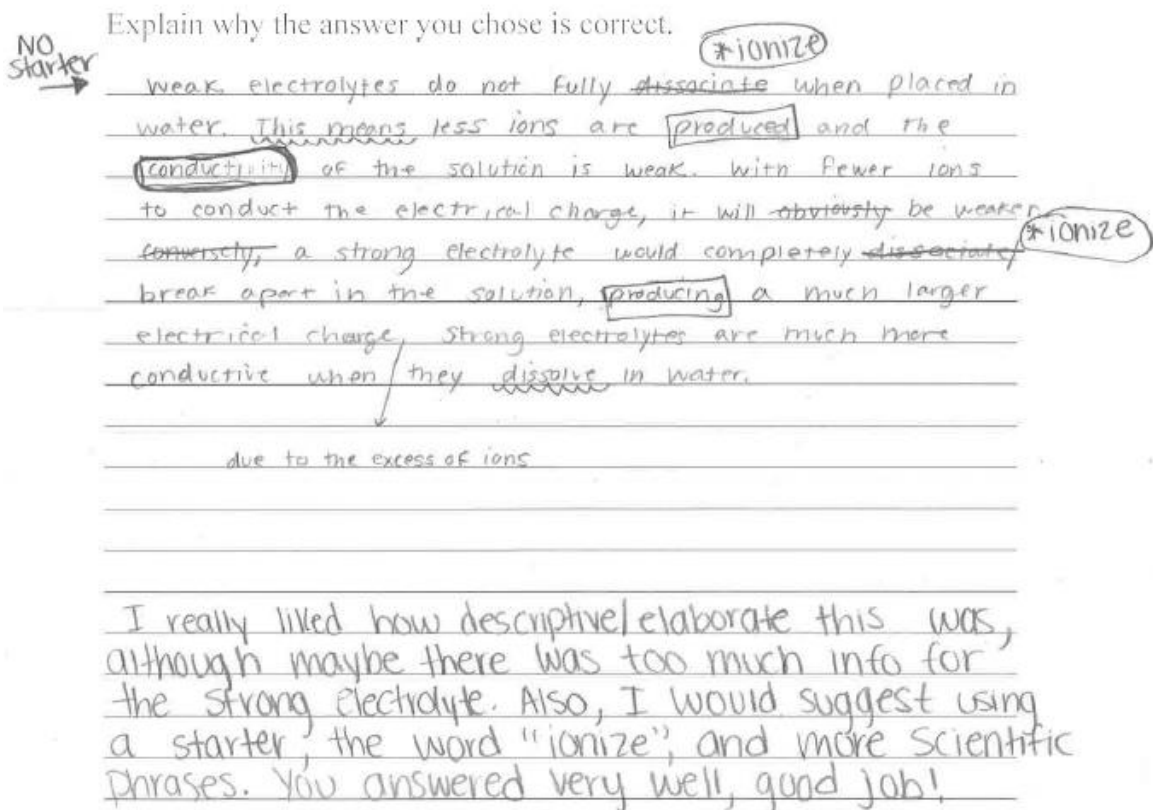


Figure 3. Peer-reviewed annotation.

As the treatment phase progressed the tiered questions moved from multiple choice to open-ended. Again, students were constantly receiving feedback regarding their

scientific understanding and scientific writing ability. Students were challenged to be metacognitive throughout the writing process.

Upon conclusion of the Solutions unit, students participated in a post-treatment Likert survey (Appendix A) which contained some of the same questions as the first survey and additional questions asking about student attitude towards literacy in science (Appendix H). Students also produced post-treatment writing samples (Appendix B) that were scored using the same rubric as the pre-treatment writing sample for comparison (Appendix C). At this point, students in the control group were given the same post-treatment Likert survey, attitude survey, and post-treatment writing prompt. Once writing samples were analyzed, select students in the treatment group were asked to participate in a short interview (Appendix I).

Data Collection

The data collection triangulation matrix used to answer the research question and secondary questions, and to evaluate the efficacy of the treatment is shown in Table 3. Along with these data, a journal of observations was generated throughout the treatment. Observations such as student attitude toward treatment, particular students of interest, and challenges I encountered were recorded. Baseline data was collected prior to the treatment phase. This data included the Likert survey and pre-treatment student writing samples (Appendix A and B). The survey questions were divided into two categories; confidence in reading/analyzing scientific text (questions 1-6) and confidence in scientific writing ability (questions 7-11). The survey was used to compare student assessment prior to intervention and post-intervention, and used as data to analyze sub-

questions one and three (Table 3). The pre-treatment student writing sample (Appendix B) was scored against our school's fifth science PBGR (Table 1) and the first school-wide transferrable skill (Table 2). Specifically, each writing sample was scored against the checklist that was created using the 'proficient' category of these skills (Appendix C). The data collected from the pre and post-treatment writing samples were used to answer sub-questions one and two of the AR project (Table 3). The writing samples from the pre and post-treatment period in the treatment groups were compared for change throughout the intervention. Laterally, the post-treatment writing samples from the treatment and control (or non-treatment) group were compared as well.

Table 3
Triangulation Matrix

Focus Question: Will the focused use of disciplinary literacy techniques allow chemistry students to demonstrate their understanding of content specific language and data analysis through writing?			
Secondary Questions	Data Source		
Question 1: Will literacy techniques increase student comprehension of content specific language?	Pre-intervention writing sample (language)	Annotated Student work	Post-intervention writing sample (language)
Question 2: How do focused literacy techniques increase students' ability to argue with evidence?	Pre-intervention writing sample (data/evidence)	Tiered Questions	Post-intervention writing sample (data/evidence)
Question 3: Are students better able to think like a scientist throughout the intervention?	Student survey pre-intervention	Student attitude survey and interview questions	Student survey post-intervention

In addition to the pre and post-treatment data collected, other data collection tools were used throughout the intervention. Tiered questions (Appendix E) were looked at through two lenses: Did the student understand the science? And was the student able to convey their ideas using appropriate scientific language? Students always received feedback on the tiered questions and were shown different responses during the next intervention day. Anonymous text annotations (Appendix G) were used periodically to provide feedback of student growth and/or challenges throughout the intervention and increase student metacognition. This feedback also helped guide the intervention to focus on the most pressing needs of the students.

Upon conclusion of the treatment phase, all students answered seven survey questions that addressed student attitude toward learning writing in a science classroom (Appendix H). These questions were asked in addition to the Likert Survey questions (Appendix A). Both the treatment and control (non-treatment) group participated in these surveys. Six students were asked to participate in interviews (Appendix I) that aimed to expand on the attitude questions and assess student perception of the intervention and of the importance of literacy in science. Three of these students were selected due to their growth throughout the intervention. The other three were selected randomly.

DATA AND ANALYSIS

The checklist used to assess student work for the pre and post-treatment writing samples were scored on a scale of 0 to 8. If the student successfully demonstrated an “I can” statement, they received one point. Writing samples were assessed by myself and another teacher. The average score for the pretreatment writing sample was 3.87

($SD=1.97$) and the average score for the post-treatment writing sample was 4.67 ($SD=2.22$). To test the hypothesis that the means were equal, a paired t-test was performed. According to the data, there was a statistical difference ($p > 0.05$) in the scores for pretreatment and post-treatment samples; $t(62) = -2.31, p = .024$.

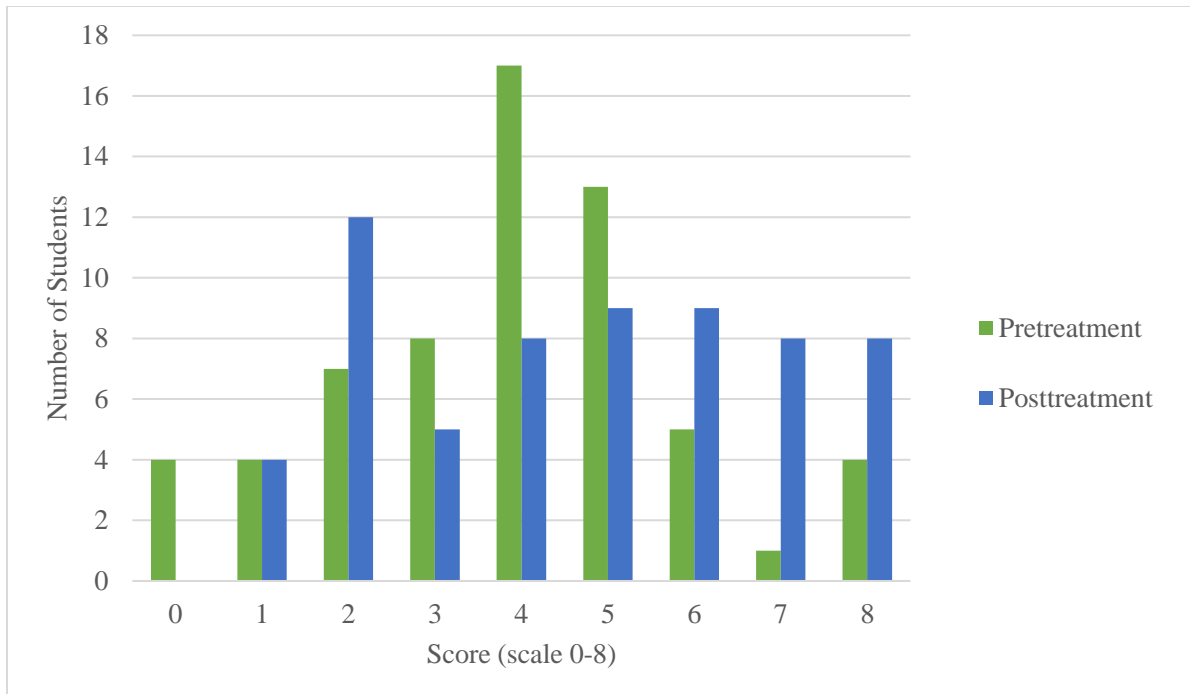


Figure 4. Pre and post-treatment writing scores for students in treatment group, ($N=63$).

Between the treatment and the control group, the average score of the treatment group on the post-treatment writing assessment was 4.67 ($SD=2.22$) and the control group was 3.06 ($SD=2.11$). In the treatment group, 63 students participated and in the control group, 32 students participated. The comparison shown in Figure 5 is reported in percentages of students achieving each score rather than number of students due to the discrepancy in the number of students assessed between the two groups.

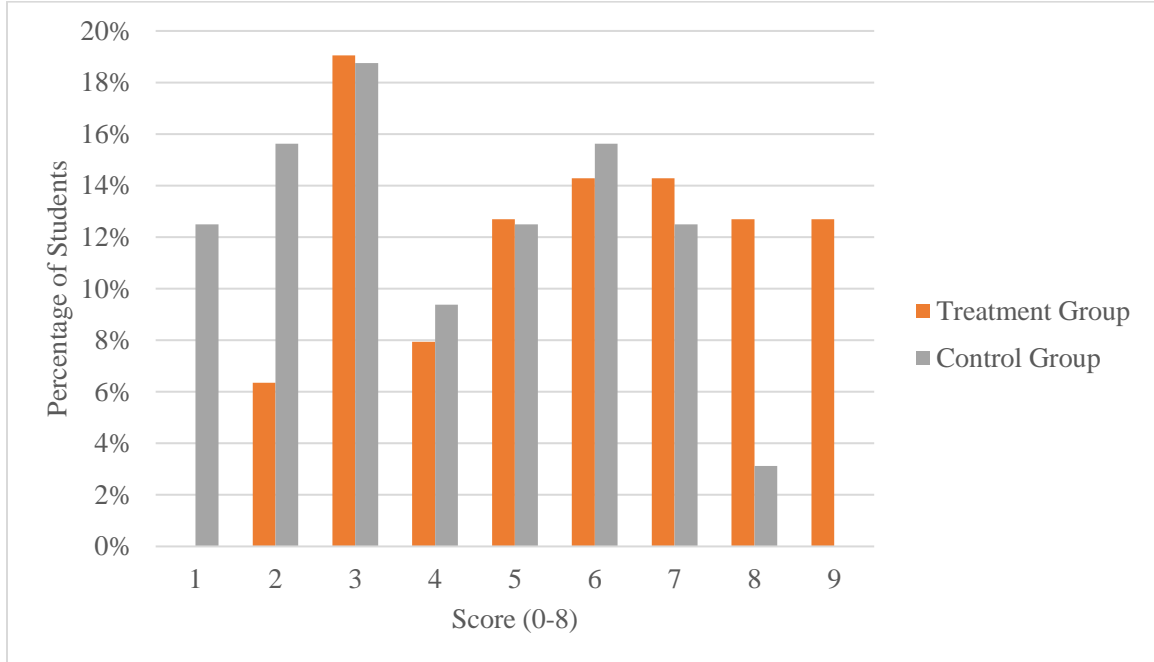


Figure 5. Post-treatment writing sample scores in treatment group, ($N=63$) and control group, ($N=32$).

Content Specific Language

One of the goals of this AR project was to question whether literacy techniques increased the use of content specific language. To assess this, the pre and post-treatment writing samples were analyzed based on two of the statements on the checklist; whether students could “use information from multiple appropriate sources (class notes, readings, videos, models, and data) to develop an answer to the question” and “use appropriate language specific to the topic and create a complete, concise, and well-structured response” (Appendix C). It was found that 75% of the students were successful in using information from multiple sources prior to treatment and 71% were successful post-treatment. Prior to treatment 38% of students were successful in using content specific

language and 63% were successful post-treatment ($N=63$). This information is shown in Figure 6.

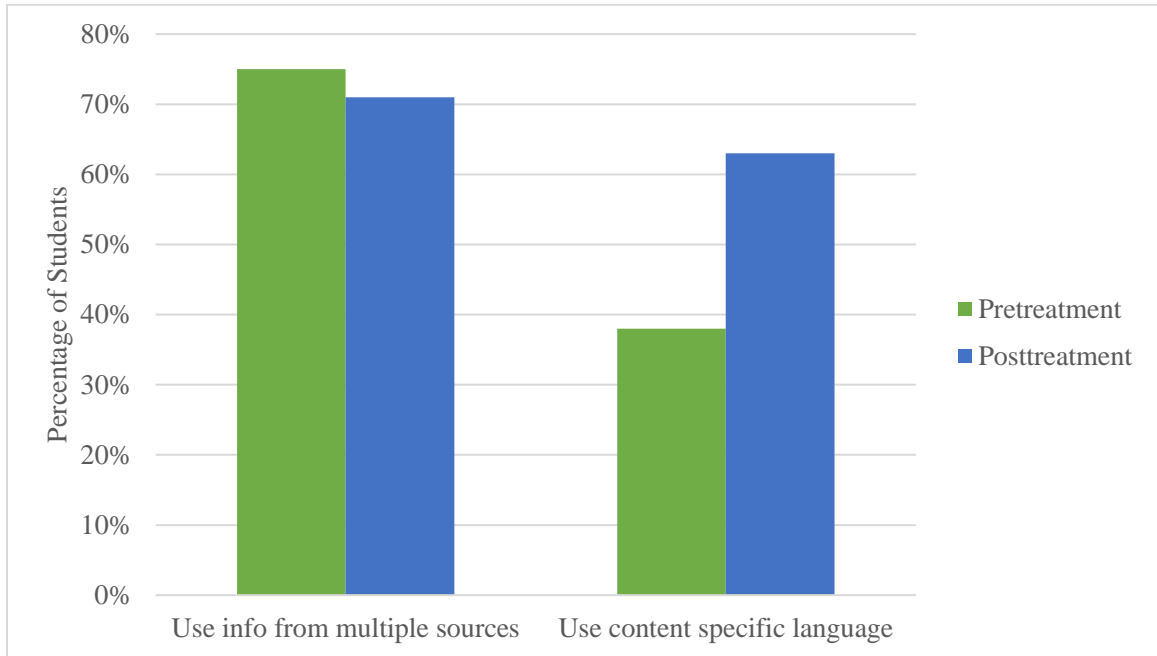


Figure 6. Pre and post-treatment success using content language in treatment group only, ($N=63$).

Both the treatment and control group had similar abilities to synthesize information from multiple sources; 71% of the treatment group compared to 69% of the control group (Figure 6, Figure 7). Add statement regarding post-intervention results for both groups regarding their ability to synthesize information from multiple sources.

Add statement regarding pre-intervention results for use of content specific language. After the intervention, 69% of the treatment group demonstrated success in using content specific language. In the control group, 44% of students were able to demonstrate this similar skill (Figure 7).

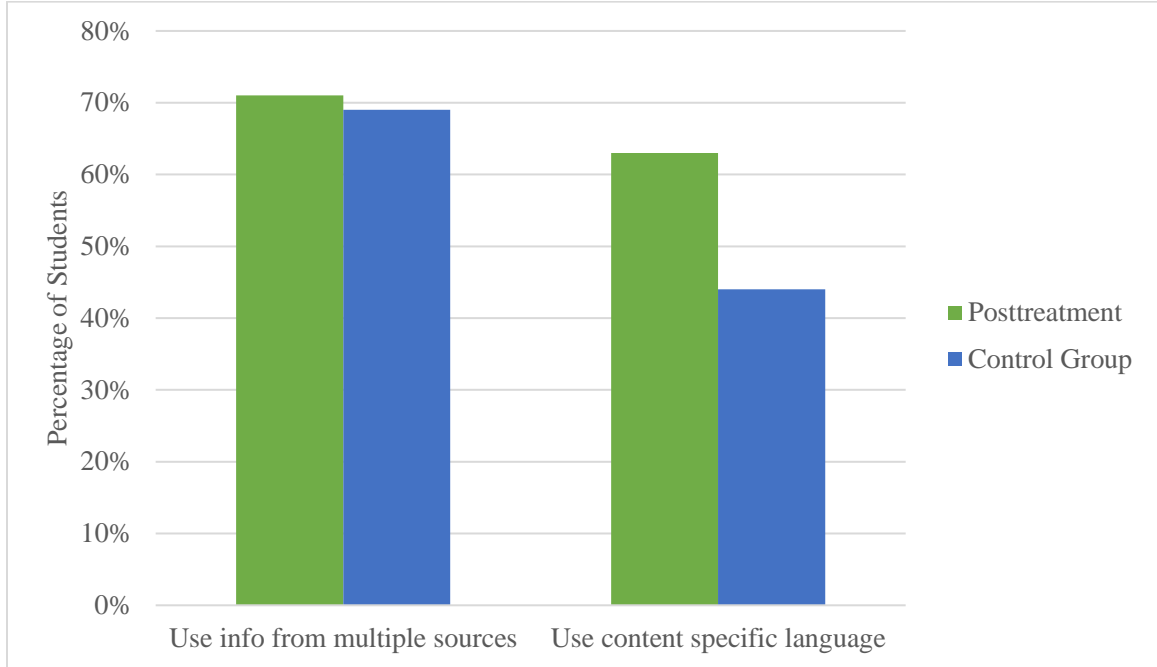


Figure 7. Percentage of treatment, ($N=63$) and control group, ($N=32$) students who demonstrated use of content specific language.

Use of Evidence and Data in Writing

To analyze the data associated with use of evidence and data in student writing, the pre and post-treatment writing samples were analyzed based on two other statements on the checklist; whether students could “create a product using (at least 2) different formats/types of evidence that addresses, but is not entirely focused on the original question” and “use reasoning and evidence to support a claim and develop a well-reasoned argument” (Appendix C). For the treatment group, there was no significant difference in ability to use multiple types of evidence to answer a scientific question. Before and after treatment, 56% of students were able to synthesize information from multiple sources and cite evidence. However, before treatment, 54% of students were

able to use data and evidence in their writing compared to after treatment, 67% of students were able to ($N=63$). This information is shown in Figure 8.

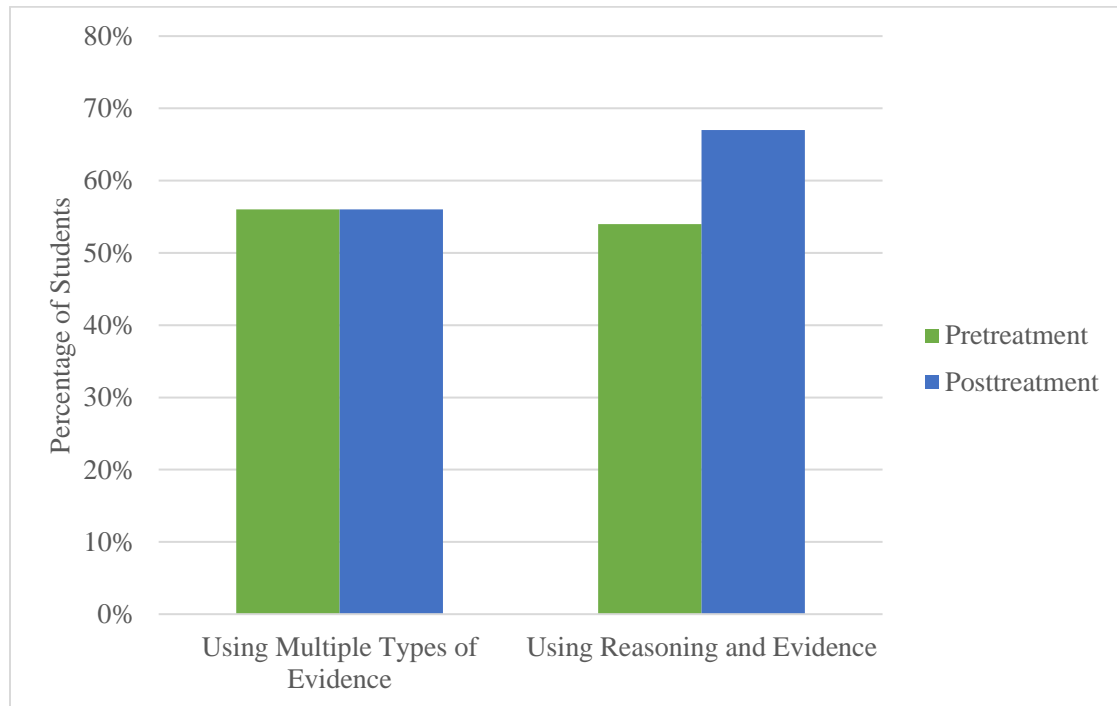


Figure 8. Pre and post-treatment success using data and evidence in writing ($N=63$).

When comparing the results of the treatment group and the control group for utilizing data and evidence in writing there was a greater margin of difference. When considering the use of multiple types of evidence after treatment, 56% of the treatment group and 38% of the control group demonstrated success (Figure 9). After the intervention, 67% of the treatment group was successful in using reasoning and evidence to support a claim whereas 28% of the control group demonstrated the same strength.

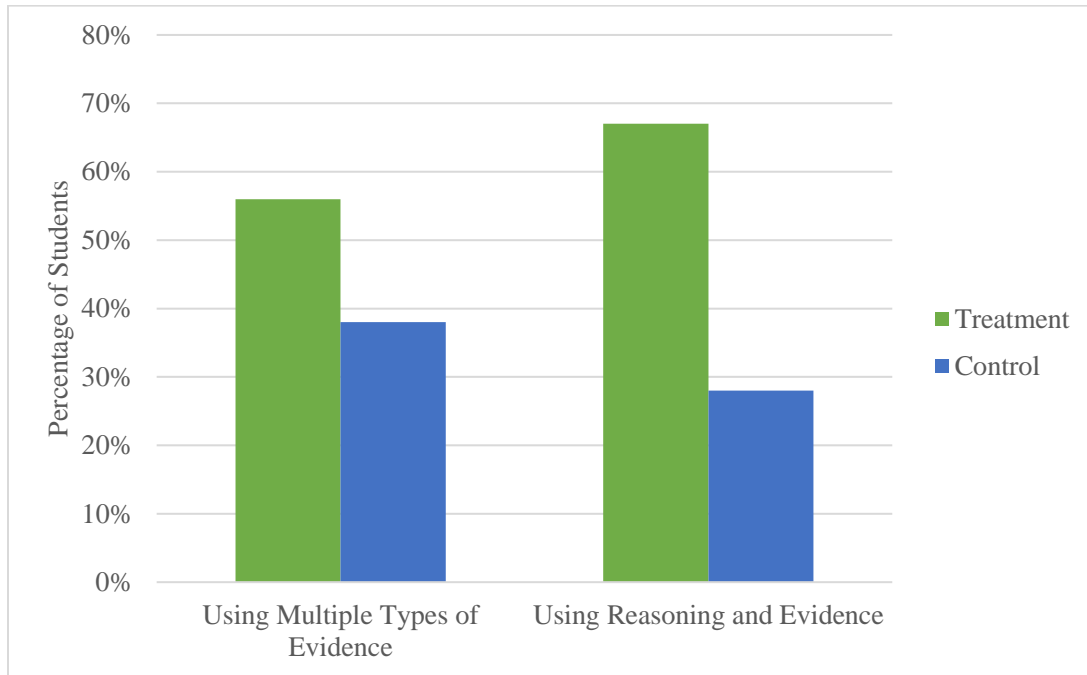


Figure 9. Percentage of treatment ($N=63$) and control ($N=32$) group students who demonstrated ability to utilize data and evidence in writing.

In addition to the pre and post-treatment writing samples, student results on the tiered questions were analyzed. The first tiered question and the last tiered question given in class were analyzed according to whether the students used the correct language and evidence (Appendix E and F). In the first tiered question, 50 of 63 total students answered the question correctly, where as in the last tiered question, 61 out of 63 students answered correctly. Students with incorrect answers to the multiple choice were still given feedback on their written response, however their data is not included in any of the following results.

For those students that did not have appropriate scientific language, their use of scientific evidence is shown in Figure 10. From the first question to the last, there was a drop in the percent of students who used scientific evidence in their response, either

correct or incorrect evidence. From the first question to the last, the students who had incorrect use of scientific evidence dropped from 50% to 16%. The students who did not use any evidence in their response increased from 2% to 3%.

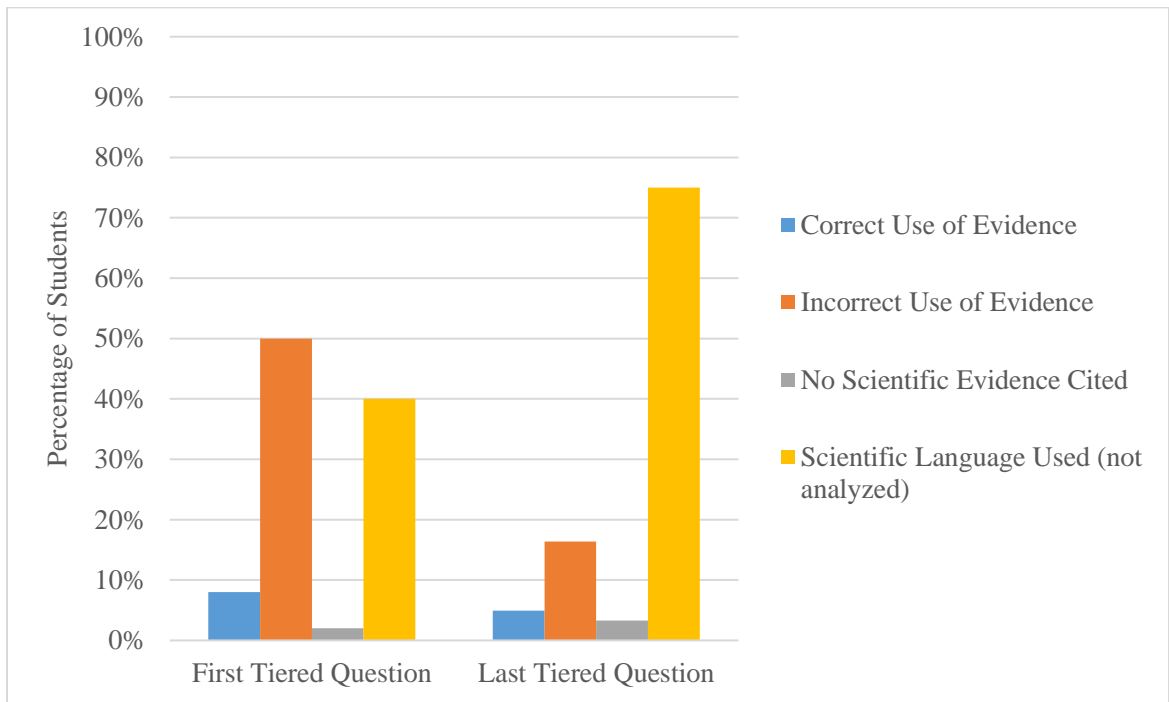


Figure 10. Treatment group use of evidence in responses that did not contain content specific science language in the first question, ($N=50$) and the last question, ($N=61$).

As shown in Figure 11, the students who did not use content specific science language decreased from 60% to 25%, meaning that 35% more students were able to better use scientific language in their answers from the first tiered question of the treatment phase to the last. There was also substantial growth in the percent of students that successfully used correct evidence to support their response from the first question (12%) to the last question (38%).

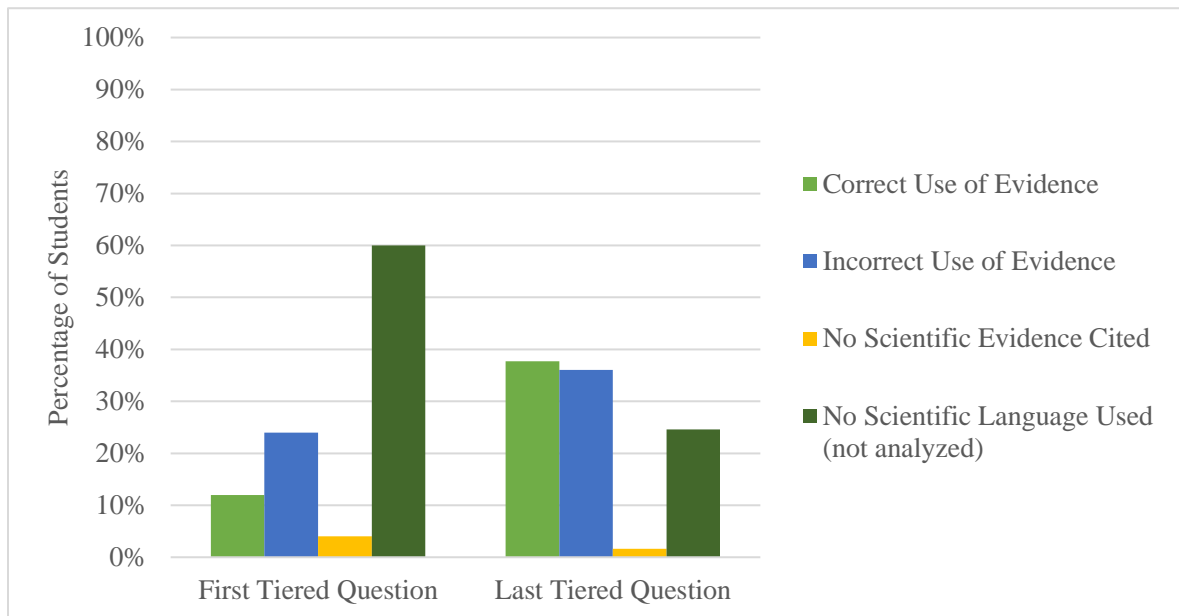


Figure 11. Treatment group use of evidence in responses that did contain content specific science language in the first question, ($N=50$) and the last question, ($N=61$).

Ability to think like a Scientist

The pre and post-treatment Likert survey was utilized to assess student self-perception of ability to read and communicate like a scientist. The questions were separated into two categories for analysis; perception of understanding of scientific texts, and graphs and perception of ability to communicate scientific information. The control group submitted the survey once, at the same time as the treatment group submitted the post-treatment survey.

When asked about personal perception of ability to read and understand scientific texts and questions, positive responses (either agree or strongly agree) increased 12% from before treatment to after treatment. Students in the treatment group who responded neutrally to the questions decreased by 9% and students who responded negatively

(disagree or strongly disagree) decreased by 4%. The control groups' responses are shown in Figure 12 below along with pre and post-treatment responses.

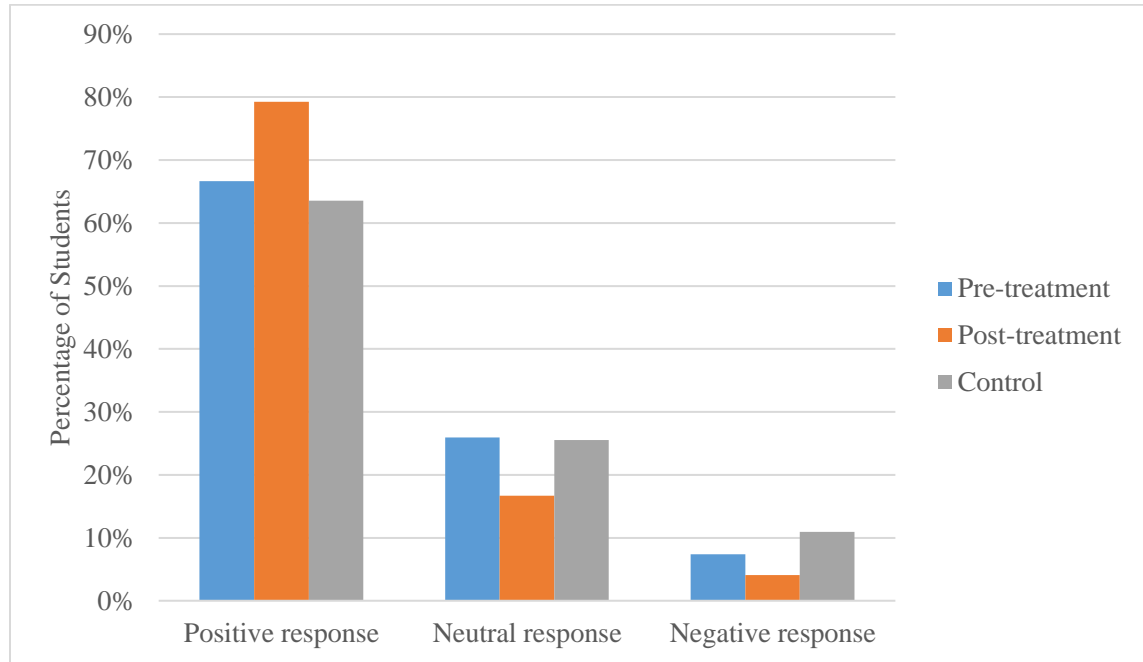


Figure 12. Student responses to Likert survey questions regarding perception of ability to read and understand science texts and graphs. (Control group, $N=32$, Treatment group, $N=63$)

Students also responded to questions that analyzed their perception on their ability to communicate scientific data information through writing. Prior to treatment and within the control group, high percentages of students felt positively (agree and strongly agree) about their ability to communicate scientific information effectively (Figure 13). Prior to treatment, 75% of students in the control group felt they could effectively communicate scientific information. This percentage rose to 83% after the treatment. The percent of students that responded neutrally to these questions fell by 8% over the course of treatment and the negative (disagree and strongly disagree) fell by 2%.

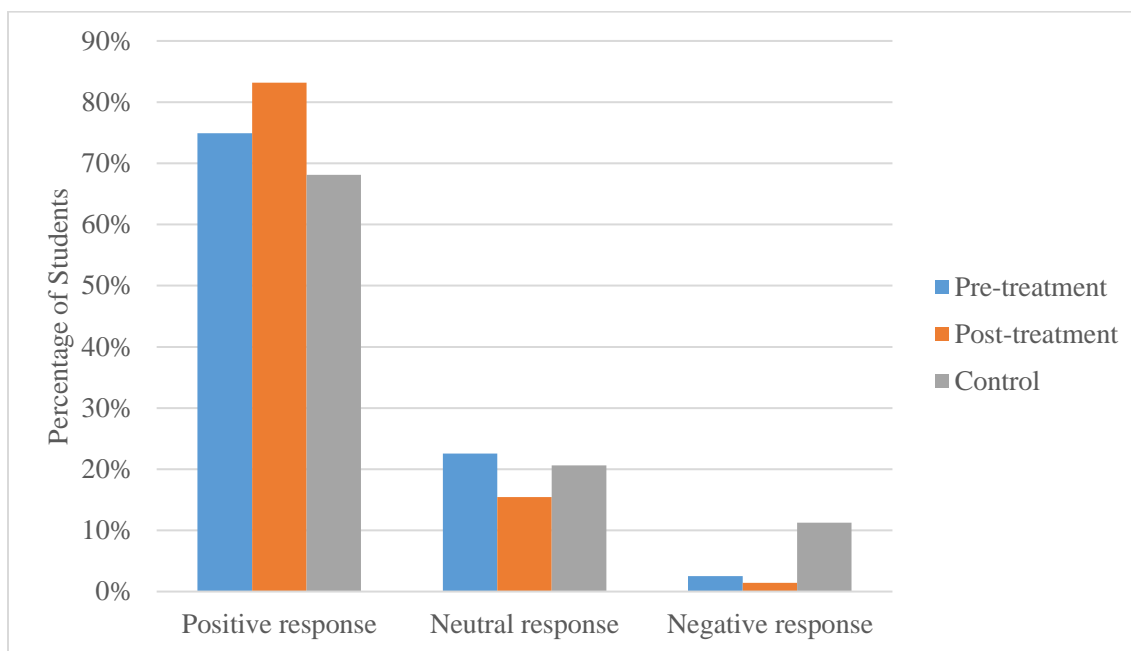


Figure 13. Student responses to Likert survey questions regarding perception of ability to communicate scientific information and data. (Control group, $N=32$, Treatment group, $N=63$)

In addition to the pre and post-treatment Likert survey questions, additional questions were added to the post-treatment survey to gauge student attitude about learning literacy techniques in a chemistry classroom. These questions were also given to the control group. In both the treatment group and the control group, almost three quarters of students had a positive response (78% and 74%, respectively) to the value of learning vocabulary and literacy techniques in chemistry. In the treatment group 13% of students felt neutrally as to the value of learning these skills and 18% of students in the control group felt similarly. Of students in the treatment group, 9% felt negatively towards learning these skills and 8% of the control group did as well.

Two specific questions on the attitude survey were looked at individually. I was interested as to whether students had learned literacy skills in a science classroom before

and whether they felt all science classes should incorporate literacy-based activities (Figure 14). Looking at all of the students who participated in the attitude survey (control and treatment), 47% of students said they had learned literacy skills in a science class before and 29% of students said they had not. The remaining 24% of students chose “neutral” which they were instructed to choose if they were unsure or couldn’t remember. When asked if they felt literacy-based activities should be in the classroom, 67% of students responded positively and only 3% responded negatively.

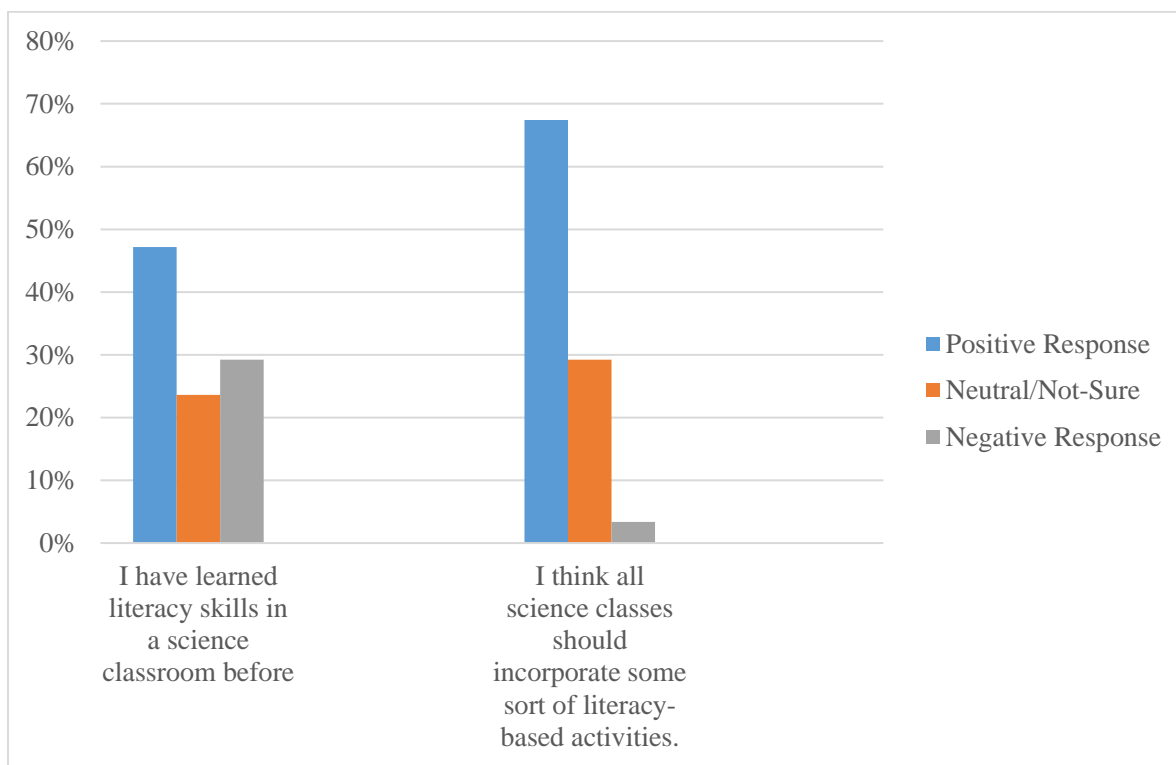


Figure 14. Student responses to two attitude survey questions ($N=89$).

INTERPRETATION AND CONCLUSION

The treatment used in this study provided significant amounts of data which provided some indication that teaching literacy techniques in a science classroom increases student critical thinking skills in chemistry as demonstrated through reading

and writing. Throughout the treatment, student writing scores increased. Not only did scores increase on the pre and post-treatment writing prompts, but formative data collected from additional tiered questions and quick verbal check-ins with students also showed an increase in writing ability and understanding of content.

The increase in quality of written work may stem from student work with vocabulary terms. In two student interviews, the students made it clear that having sentence frames and vocabulary terms on the wall was helpful. One student responded, “I used to just write any word that I could recall down, even if it was wrong. Having the words on the wall made it easier to remember which was the right one I should be using.”

Writing while synthesizing information from multiple sources and using data as evidence still continues to be a challenge. Of the 75% of students that were able to use scientific language and vocabulary in the last tiered question, only 38% of them were able to also incorporate the correct use of evidence and 36% were unable to do so. In the first tiered question, 60% of the students did not demonstrate proper use of scientific language. Some of these students shifted and were able to demonstrate this skill after treatment. While this is a positive outcome in terms of vocabulary usage, some of these student may not yet be at the point of incorporating evidence correctly, which could indicate why a large percentage (36%) were still unable to incorporate scientific evidence. Had the tiered questions not been anonymous, I would have been able to see how each student shifted throughout the tiered questioning process.

Additionally, there is inherent error in the fact that the tiered questions were not the same throughout the treatment. The last question was conceptually more challenging,

but given that the content contained in the question was the topic for four weeks of class, I was not surprised that more students were able to correctly answer the multiple choice portion of the question. Fifty students of 63 answered the first question correctly, while 61 were able to answer the last one correctly.

The data also showed a difference in the writing prompts collected from the treatment group (post-treatment) and the control group. The treatment group scored an average of 4.67 out of 8 and the control group scored an average of 3.06 on the same writing prompt. While this is an indication the treatment showed effectiveness, there are considerations to be made in a study like this. The control group contained students taught by another teacher. While the other teacher and I teach the same content in a very similar order, we have two different teaching styles. The control group students were exposed to the same content, but in a different manner. It should also be considered that because the samples were collected in April, the students had been exposed to over seven months of writing expectations from their respective teacher. My expectations are most likely not exactly the same as my colleague. When designing this Action Research project, I struggled with utilizing one of my own classes as a control group. Had I done this, bias could be removed in these comparisons. However, I could not in good conscience, leave out a group of my students for control purposes when my hope was that the treatment could be a benefit.

Of all of the strategies employed, students responded very positively to the anonymous text annotation. In all three classes, at least one student asked when they could see the markups on their own work after I collected it. During the student

interviews, a student mentioned that “seeing what other people do right and wrong is helpful in making sure I don’t make the same mistakes or making sure I do things similarly.” This type of peer review is something I plan to use more commonly.

A majority of the students seemed eager to partake in these activities. One student said upon introduction of the literacy instruction, “Good! I need to know how to write using data. I never know what you mean when you write that on a lab report.” Remarks like these, along with the attitude survey showed that students found value in learning literacy skills in their science class. There was also a lot of positive responses on the attitude survey about the importance of knowing how to understand and communicate scientific information.

VALUE

I never doubted the importance of literacy in a science classroom, but it became more apparent with shifts in the school culture toward Common Core Standards and the Next Generation Science Standards. Discussions at both faculty and department meetings opened my eyes to the injustice students are receiving in terms of not being taught literacy in all content areas. Teaching physical science, which is largely math based, seemed like the perfect fit to insert literacy-based instruction.

This process of developing and implementing this AR project has changed my teaching and thinking in a number of ways. Most importantly, I have become more aware of the fact that my assessment of student content knowledge through writing was inadequate given the scientific writing skills students have. If a student does not know what information to use, how to properly use data, or how to formulate a sentence using

the correct content language, how can I fully assess their understanding? By filling the students' toolboxes with literacy tools, they can become better at choosing data and vocabulary to formulate a clearer response to show their understanding.

I also recognized that taking 15-30 minutes a few times a week to incorporate writing and vocabulary activities did not take away from teaching the content. Teachers are constantly worried about having enough time to teach all we are expected to and want to. Even though I gave up least an hour of class time each week to literacy based discussions and activities, I learned that it is possible to incorporate content into those activities.

I found a lot of value in keeping a "teacher journal" and continued using it after the intervention. While it provided some formative data in the form of observations throughout the treatment, I found that it was a great way to keep track of what did and did not seem to work in the classroom in one place. It did not lead to data that was particularly useful in this study, but I got into the habit of writing down notes about content, lessons, misconceptions, student attitudes, and ideas. This led to more intentional personal reflection about my teaching. Flipping through the pages at the same time next year will help guide how I change my teaching of the same content.

It became apparent to me that I will always be a student. I thought of myself solely as a science teacher, not a writing teacher. However, I quickly realized during my work throughout this project the need of students to learn and practice reading and writing skills in all content areas. In order for me to effectively teach these skills, I had a

lot of learning to do and to continue teaching these skills I still have a lot more learning to do.

The positive remarks and dedication of my students reinforced my effort to constantly change and adapt my practice to benefit their learning. I have already been planning to incorporate some of these activities very early on in the 2016-2017 school year.

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APPENDICES

APPENDIX A
STUDENT LIKERT SURVEY

Student Survey of Ability to Effectively Understand Science Concepts through Reading and Writing

All scientists must possess the skill of writing clear and effectively. Scientists must synthesize information from a range of sources into a coherent piece of work that explains a topic or process. Below, I will ask you a few questions on your personal interpretation of your scientific reading and writing skills. Please be honest. NOTE: participation is voluntary and you will not be graded on your answers.

* Required

I feel comfortable and confident in my ability analyze scientific texts. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

I feel confident in my ability to analyze a data table or graph. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

When reading our textbook, I am confident in my ability to understand the information presented. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

When reading a scientific article, I am confident in my ability to understand the information presented. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

I refer to figures presented in texts while I read for clarification. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

When reading, if I come across a word I don't know, I look it up. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

I feel comfortable and confident in my ability to cite evidence when writing. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

If given a data table or graph, I could effectively communicate the findings shown in the data table through writing. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

I am confident in my ability to cite data when writing. *

I can use values to support my ideas.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

I can use terms we learn in class effectively when I write. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

I feel confident in my ability to communicate scientific information through writing. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

APPENDIX B

PRE AND POST TREATMENT WRITING PROMPT

APPENDIX C

PRE AND POST-TEST WRITING SAMPLE SCORING GUIDE

Science PBGR 5 – Synthesis

I can...

- use information from multiple appropriate sources (class notes, readings, videos, models, and data) to develop an answer to the question
- create a product using (at least 2) different formats/types of evidence that addresses, but is not entirely focused on the original question
- answer a focusing question and support **most, but not all** of my claims with evidence
- limit my product to what is essential to answering the focus question

Score ____/4

Transferable Skill 1 – Evidence and Logic in Communication

I can...

- synthesize evidence to support analysis, including implicit and explicit meanings in sources
- evaluate the relevancy, accuracy, and completeness of evidence that has been used to support the claims
- use reasoning and evidence to support a claim and develop a well-reasoned argument.
- use appropriate language specific to the topic and create a complete, concise, and well-structured response

Score ____/4

APPENDIX D

WORD WALL AND ANCHOR CHARTS

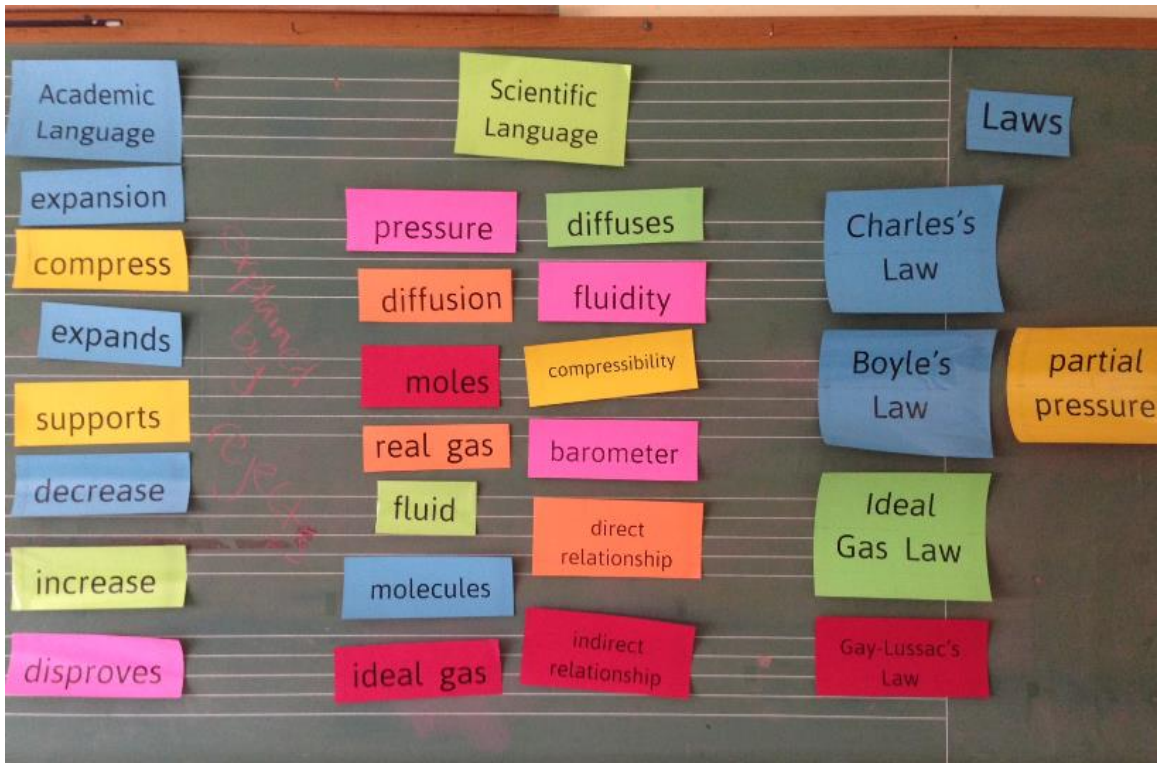
The image shows two pieces of handwritten paper with notes. The left paper is titled 'Data' in red and contains five bullet points with blank lines for answers. The right paper is titled 'Analysis and Conclusions' in green and contains five bullet points with blank lines for answers. The background is dark with some green letters visible at the top.

Data

- ✧ The evidence supports this idea because _____.
- ✧ Another example that supports this idea is _____ because _____.
- ✧ The effect of _____ on _____ is _____.
- ✧ The results were _____.
- ✧ _____ and _____ were compared to _____ (i.e. determine a relationship).

Analysis and Conclusions

- ✧ Based on the data, it can be inferred _____.
- ✧ If _____ is changed then _____ will happen because _____.
- ✧ After observing _____, it can be inferred (concluded) _____.
- ✧ The pattern noticed was _____.
- ✧ The data could have been affected by _____.
- ✧ The experiment showed (that) _____.
- ✧ Based on these results, it can be concluded (that) _____.



APPENDIX E
SAMPLE OF TIERED QUESTIONS

The rate of diffusion is _____ in liquids than in gases.

- a. slower
- b. faster
- c. the same

Explain why your choice is correct.

Water forms spherical drops because of:

- a. viscosity
- b. capillary action
- c. surface tension
- d. fluidity

Explain why your choice is correct.

What happens when a weak electrolyte dissolves in water?

- a. The boiling point decreases
- b. The solution does not conduct electricity.
- c. Few ions form.
- d. 100% of the molecules ionize.

Explain why the answer you chose is correct.

APPENDIX F
TIERED QUESTION GRADING CATEGORIES

Correct Answer: ____ out of ____

	Correct Science/Evidence	Incorrect Science/Evidence	No scientific evidence cited
Use of scientific language			
No use of scientific language			

Incorrect Answer: ____ out of ____

	Correct Science/Evidence	Incorrect Science/Evidence	No scientific evidence cited
Use of scientific language			
No use of scientific language			

APPENDIX G

TEXT ANNOTATION AND FEEDBACK DIRECTIONS

- # Providing Feedback
- { 1st Analysis Question
- Give suggestions:
- ① Does it include data?
 - ② Does it use science language
(i.e. increase vs. "goes up"
equations explained)
 - ③ Is it clear + concise?
 - ④ Are science concepts accurate?
- { Sentence frames + word wall

TEXT ANNOTATION

- ① Underline any sentence starters or common frames we have discussed
- ② Circle any content-area vocab
- ③ Box any academic terms we've discussed
- ④ ~~Cross~~ out unneeded transitions/words
- ⑤ Assign proficiency (E, A.P., P., B.P.)
emerging, almost prof., prof., beyond prof.
- ⑥ CONSTRUCTIVE feedback

APPENDIX H

STUDENT POST INTERVENTION ATTITUDE SURVEY

I feel it is useful to learn science vocabulary (having a word wall, writing definitions, etc.) *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

I would like to have 'word walls' (or vocabulary terms posted around the room) during every unit for use while writing responses. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

I have never learned writing skills in a science class. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

I feel it would be (or is) useful to learn writing skills in a science class. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

I think being able to communicate science through writing is important. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

I think being able to understand scientific writing is important. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

I think all science classes should incorporate some sort of literacy-based activities. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

APPENDIX I
STUDENT INTERVIEW QUESTIONS

Student Interview Questions

1. Has your opinion about Chemistry changed as the year progressed? Why or why not?
2. Do you think your ability to understand the textbook and other scientific articles has improved over the course of this year? Why or why not?
3. Do you think the ability understand scientific articles, whether journal articles, news articles, or textbooks is relevant? Why or why not? Is one type more important than the other?
4. Do you think the focused use of sentence framing and annotating texts helped you better write scientifically? Why or why not? (Was it helpful to have those on the board in the classroom?)
5. Why, if you agree, do you think it is important to be able to explain what you see on a graph?