THE IMPACT OF CLAIM-EVIDENCE-REASONING WRITING TECHNIQUES ON ARGUMENTATION SKILLS IN SCIENTIFIC INVESTIGATIONS

by

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ABSTRACT

When making arguments in scientific writing, students struggle with using evidence and reasoning when making claims. Over the course of six weeks, ninth grade biology students were introduced to the claim, evidence, reasoning (CER) framework to help organize and develop scientific arguments in science lab conclusions. This research included a survey and writing assessment both before and after introduction to the CER framework. The purpose of this research was to determine if the CER framework would increase the frequency that students used evidence and reasoning when making their claims. Results of this study indicate that the CER framework did increase student use of evidence and reasoning in claims. Results also indicate that the CER framework did not have an effect on student ability to use scientific principles in their reasoning.

INTRODUCTION AND BACKGROUND

The research in this paper was done during my 4^{th} year teaching at Elk Grove High School. Research took place in a 9^{th} grade biology classroom over the course of the 2016-2017 school year. During this same school year, I also taught 10^{th} grade chemistry and 12^{th} grade advanced placement environmental science. Before this school year, I have had experience teaching physical science and physics.

Student Demographics

Elk Grove High School is located in the northwest suburbs of Chicago in Elk Grove Village, Illinois. The school has a student enrollment of approximately 1,993 students and a graduation rate of 92%. Forty-two percent of the student population is considered low income. The racial and ethnic breakdown of the student body is 46.8% white, 39% Hispanic, 8.3% Asian, 3% black, 2.8% multi-racial, and 0.1% American Indian. Approximately 7.5% of students are English learners.

Topic of Research

The Next Generation Science Standards (NGSS) include eight science and engineering practices, two of which relate to using argumentation with evidence and reasoning. These represent skills that many of my students have struggled with in the past. Students will not always cite data from an experiment, and when they do, they struggle with explaining why the data is important in supporting or refuting a claim or hypothesis made prior to carrying out the experiment. The research in this paper focuses on using a claim-evidence-reasoning (CER) framework to help develop explanatory and argumentative writing skills in scientific investigations. Specifically, the CER framework was used in scientific investigations as a way to guide student explanations and arguments for claims made in response to questions.

The main question that my research attempts to answer was: What are the effects of the direct instruction of the CER framework on conclusion writing in scientific investigations? Sub questions include: How does the CER framework affect the frequency that data is used when supporting an argument from evidence? How does the CER framework affect the frequency that students use reasoning to link evidence to their original claim? Will the practice of writing with the CER framework improve student confidence in using scientific concepts in their reasoning?

CONCEPTUAL FRAMEWORK

This section seeks to investigate argumentative and explanatory writing. Included is the definition of argumentative writing and what in contains, the importance of argumentative writing in the scientific field, struggles that students currently have with argumentative writing at various levels in education, and research that has been done that pertains to argumentative writing in secondary classrooms.

Scientific argumentation is an attempt to validate or refute a claim based on evidence and reasoning. (Sampson & Schleigh, 2016, p.ix) A claim is defined as an explanation or conclusion that provides an answer to a question in research. Evidence represents the data or findings in an investigation, while the reasoning refers to the support that is offered for the claim.

The importance of argumentative writing in science is reflected in the recommendations of professional organizations and widely adopted science standards such as the NGSS. In reference to students' ability to do scientific inquiry, the National Science Teachers Association recommends that science teachers help students "learn how to draw conclusions and think critically and logically to create explanations based on their evidence" (Nation Science Teachers Association, 2004). The importance of argumentative writing in the NGSS is seen in the science and engineering practices. Practice six of the NGSS relates to constructing explanations for the causes of phenomena, while practice seven relates to engaging in arguments from evidence necessary to defend and advance an explanation. (NGSS Lead States, 2013) These standards rely on skills such as making claims, gathering and evaluating evidence, and using the evidence to reason and support or refute a scientific claim.

While these skills may be emphasized by professional organizations and are widely accepted science standards, the skills needed in scientific inquiry in which students use evidence and reasoning to support an argument are not always part of classroom instruction (McNeill & Krajcik, n.d.). Multiple studies have been done to indicate that student lack proficient argumentation skills in the science classrooms. One study of eight middle school classrooms found that only 18.1% (*N*=72) of students constructed explanations with the three components of claim, evidence, and reasoning (Ruiz-Primo, Li, Tsai & Schneider, 2008). Forty percent of students made claims without providing any evidence or reasoning. This study did find, however, that a positive correlation existed between students' high quality explanations and student performance in class that was unrelated to argumentative writing. The study proposes that exposing students to the development of explanations can lead to better understanding of topics, but opportunities to develop these types of explanations are limited. The study continues by maintaining the position that adequate guidance during the formative and summative assessments of explanations is crucial. Teachers that implemented notebooks that scaffold students into the organization of claims, evidence, and reasoning provided structure for the students, while still allowing students to think independently. Teachers that used notebooks with less guidance provided structure, but lacked focus, and notebooks with too much guidance allowed for copying of information without much independent thought on the student end.

The struggle with writing explanations that contain evidence and reasoning is also seen in high school level science classes. A study done in introductory biology classes used software to guide students' inquiry and explanations in two separate investigations and found that in one investigation, 73% (*N*=30) of groups cited no relevant data in their claims (Sandoval & Millwood, 2005). The study continued by explaining that students also struggled with rhetorical use of evidence, or reasoning, and often failed to explain why specific evidence and data was related to their claim. This struggle with appropriate use of reasoning is seen even further in college level courses. A study of 234 undergraduate students within different levels of science courses including 100-level introduction to biology, 200-level molecular genetics, 300-level clinical microbiology, and 400-level content specific courses found that few differences were found in scores based on the ability to use evidence in claims, but did notice that there was a positive correlation between course level and ability to use reason to connect their evidence to claims (Schen, 2013). On average, 100-level students (*N*=132) cited evidence 3.1 times and used reasoning 1.78 times, while 300-level students (*N*=32) used 3.03 pieces of evidence and reasoning 2.44 times.

This previous research indicates that in earlier years of science education, students struggle with the use of evidence and reasoning in claims, while high school and undergraduate level students struggle with more complex skills such as reasoning. A comprehensive review of literature investigated the development of argumentation skills and asserts that the lack of argumentation practice, along with the lack of proper pedagogical strategies by teachers for organizing argumentation skills is making progression in the scientific field difficult (Driver, Newton & Osborne, 2008). This study maintained the position that argument in science is a central skill that is socially constructed and that scientific knowledge is gained through argumentation of claims rather than through the scientific method approach seen in many science classrooms. It is clear that argumentative writing is both a crucial skill and one that has room for improvement in the science classroom.

Teachers play an important role in the development of the difficult skill of argumentative writing. A study of secondary science teachers was done over the course of a year in which they attended workshops that developed materials and strategies for augmentation in the classroom. By examining video and audio lessons from the beginning and end of the school year, researchers determined that professional development of argumentation skills does increase exposure to argumentation practice in the classroom (Simon & Osborne, 2008). The study also indicated that teacher that included higher-order processes had students with the best argumentation skills. For teachers to support the writing of scientific explanations, researchers point to five strategies that should be implemented into the classroom. “Make the framework explicit, model and critique explanations, provide a rationale for creating explanations, connect to everyday explanations, and assess and provide feedback to students.” (McNeill & Krajcik, 2008, p.125)

It can often be assumed by teachers that students understand what it means to write a scientific argument. To approach the first strategy of making the framework explicit, educators have broken down argumentative practices into a framework that includes three components: claim, evidence, and reasoning. (McNeill & Martin, 2011, p.53) After establishing a clear understanding of claim, evidence, and reasoning, this framework provides students with structure that can help communicate their ideas.

After students gain a clear understanding of the framework, teachers also need to provide students with models of arguments, either spoken or written, and need to explicitly identify the strengths and weaknesses within the arguments. (McNeill & Krajcik, 2008, p.126-127) The next strategy is to provide a rationale for creating explanations. It should be made clear to students that scientific explanations are important in both the scientific community for use of explaining natural phenomena and also for being able to support and arguments and persuade others. Teachers should also make an attempt to connect to everyday explanations. Connecting scientific explanations to everyday examples can help apply the CER framework to prior knowledge of non-science themes. The last strategy is assessing and providing feedback to students. A study of a seventh grade team of teachers investigated the roll out of an inquiry curriculum focused on writing (Grymonpre, Cohn & Solomon, 2012). The goals of the teacher team was to move students past the phrase “just because” when writing scientific explanations. During the study, teachers used the CER framework, along with five category rubric with descriptors written in student-friendly language. After inclusion of the framework and rubric, the student growth percentile on the students’ state ELA test had a mean of 66%, which meant that two thirds of the students improved more than the average student in the state.

Research indicates that students at multiple levels struggle with argumentation in writing, but that a clear and structured framework as well as formative and summative feedback can aid in the development of argumentative writing of claims, evidence, and reasoning. My action research will therefore incorporate a CER template that students will use to draft conclusions. Students will receive formative feedback on their drafts with a well-defined rubric before constructing a final draft that will be assessed using the same rubric.

METHODOLOGY

This study examines the instruction and implementation of a CER framework in a 9th grade biology classroom. The motive behind this research was to determine if the CER framework would improve students’ ability to support claims in the science classroom through their own writing. More specifically, this study investigated how often students used data to support their claims, how often students used reasoning to link their evidence to their claim, and how often students used scientific principles or concepts when providing reasoning. This research was conducted on 9th grade biology students during February and March of 2017. The study was reviewed and approved by the Montana State University Institutional Review Board.

Participants

This study consisted of two sections of 9th grade introductory biology. The total number of student participants in this research was 41. All 41 students participated in research that involved a pre-survey and post-survey as well as the submission of writing samples. A total of eight students were chosen through random selection to participate in a pre-interview and a post-interview. This smaller research group was divided into two equally sized subgroups based on student performance on the preliminary SAT 8/9 standardized test that determined a cross-test score of “analysis in science” that ranged from 6-36. One subgroup of four had scores lower than 19 (Group A), while the other subgroup of four has scores of 19 or higher (Group B). The purpose of this research group was to measure the effect of the CER framework on students that have shown varying levels of the understanding of scientific analysis as shown through previous standardized testing.

The male to female ratio of the two combined classes was about one to one with a total of 22 girls and 19 boys. Of the 41 total students, two had an individual education plan and five had a 504 plan.

Intervention

The first half of the school year focused on instruction that related to experimental design skills such as hypothesis writing, graphing, and identification of experimental variables. The significant focus in my biology classes for the second half of the year was argumentative writing, or conclusion writing, done with provided data or data gathered through scientific investigation.

In this action research, I used the CER framework used by McNeill and Krajcik (2011), along with a CER template (Appendix A), to help students formulate their explanations and arguments. The framework breaks down scientific arguments or explanations into three components. These components include a claim, evidence, and reasoning. The claim in a scientific explanation is the answer to a specific question or problem. Often times this claim is made after a scientific investigation that was performed in response to a prompt. The evidence component of the framework includes data that is collected through scientific investigation or data that is provided from previous research. This data can be quantitative or qualitative and is use to help support a claim that has been made. The reasoning component helps connect the evidence that you have cited to the claim that you have made. Based on previous experience with conclusion writing with students, the reasoning component tends to be the most difficult. Good reasoning often times includes connections to scientific concepts and principles that help students make better sense of data and trends.

Before direct instruction on the CER framework, students were administered a pre-intervention writing assessment (Appendix B). The purpose of the writing assessment was to assess students' current ability to formulate a scientific explanation. Because I was interested in the CER framework's effect on student use of scientific concepts in their reasoning, the writing assessment provided data related to a topic that was already covered in class. The writing assessment asked students to use a set of data related to oxygen production in plants based on light type to make a scientific explanation to the question “Does the type of light affect the rate of photosynthesis?” This writing assessment was scored with a rubric that provided marks ranging from 1-4 for the claim, evidence, and reasoning (Appendix C). Students were also asked to take a pre-intervention survey (Appendix D). The pre-intervention survey served as a tool to gain insight into what my students thought a scientific explanation or claim was, and how comfortable they were with writing their own.

Direct instruction of the CER framework followed the pre-intervention writing assessment and survey and coincided with our unit on plants, photosynthesis, and respiration. Direct instruction included the explanation of the three components of the CER framework as well as the importance of it in the field of science. This direct instruction began a classroom discussion that followed the question, “Is a hot dog a sandwich?” This discussion served as a tool to introduce the importance of having evidence or reasoning in your argument in a non-science related topic. After discussion with students, I used a PowerPoint presentation to explain what a claim is, what evidence is, and what reasoning is. During this presentation, I made the connection between having these three components in a strong argument, and that these three components are also crucial to having strong scientific explanations.

Following direct instruction and the analysis activity, students conducted two scientific investigations in which they wrote scientific explanations using the CER framework and CER template (Appendix A). The CER template was developed to help students organize their explanations during the writing process.

The first investigation involved cell respiration and asked students to the answer the question “How does exercise affect the rate of cell respiration?” This guided- inquiry investigation had students design and carry out their own experiment. Students were asked to write a scientific explanation that answered the lab question using the CER format. During this investigation, I used the CER rubric (Appendix A) and helped guide students in their first use of it. After students finished their writing, they received formative feedback with the CER rubric. (Appendix C)

The second investigation involved plant transpiration and asked students to answer the question “How does the environment affect the rate of transpiration in plants?” Once again, students designed and carried out their own experiment with materials that included lamps, fans, and bell jars. Students were asked to write a scientific explanation using the CER format. Use of the CER template was once again encouraged during the writing process. After drafting a conclusion, students were asked to analyze the explanations made by students from the other class (Appendix E) and then grade the explanations using the CER rubric. Students then worked in small groups to share how they rated each explanation. A brief classroom discussion followed about the parts of the explanations that were done well and what parts needed improvement. Students then made final revisions to their writing before turning it in for formative feedback from the CER rubric.

Following the direct instruction and two investigations, students were administered the post-test writing assessment. This writing assessment was exactly the same as the pre-test writing assessment. Once again, the CER rubric was used to assess the claim, evidence, and reasoning in each explanation. Students were also given the post-intervention survey that was identical to the pre-intervention survey. Marks on the writing assessment and feedback from the survey was then analyzed and compared to the pre-intervention data.

Student interviews were also conducted with eight students (Appendix F). These interviews were done to help measure the effectiveness of the CER framework and template from the student perspective. I was particularly interested in investigating whether or not the CER framework helped students make connections to concepts from class more often than when the framework is not implemented.

All data collection instruments used in this action research is listed in Table 1.

Table 1
Triangulation Matrix

Questions	Data Source		
Focus Question: What are the effects of the direct instruction of the CER framework on conclusion writing in scientific investigations?	Pre-Intervention Survey	Post-Intervention Survey	Student Interviews
Subquestion 1: How does the CER framework affect the amount of times students write a claim when writing conclusions?	Student Pre-Intervention Writing Assessment	Student Post-Intervention Writing Assessment	
Subquestion 2: How does the CER framework affect the amount of times data is used when supporting an argument from evidence?	Student Pre-Intervention Writing Assessment	Student Post-Intervention Writing Assessment	
Subquestion 3: How does the CER framework affect the amount of times students use reasoning to link evidence to their original claim?	Student Pre-Intervention Writing Assessment	Student Post-Intervention Writing Assessment	
Subquestion 4: Will the practice of writing with the CER framework improve student confidence in using scientific concepts in their reasoning?	Pre-Intervention Survey	Post-Intervention Survey	Student Interviews

Timeline

January 30 – February 3, 2017

During this week both the pre-intervention writing assessment (Appendix B) will be conducted, followed by the pre-intervention survey (Appendix D). These results will be collected and organized for later analysis. Direct instruction of the CER template will follow shortly after.

February 6-10, 2017

During this week, the first of two scientific investigations will be performed and students will use the CER template (Appendix A) to help formulate scientific explanations using the CER framework. Students will use the CER rubric to peer-assess and I will also provide feedback following collection of their writing.

February 13-17, 2017

During this week, the second of two scientific investigations will be performed and students will once again use the CER template (Appendix A) to help formulate scientific explanations using the CER framework. We will also analyze sample student claims (Appendix E) with the CER rubric (Appendix C). Students will then use the CER rubric to peer-assess and I will also provide feedback following collection of their writing. At this point, students will have analyzed claims made by others and will have made claims of their own that have been peer-assessed and assessed by me. No data will be collected during these two scientific investigations since they are a form of formative assessment.

<u>February 20-24, 2017</u>

Students will take the post-intervention written assessment (Appendix B) and then the post-intervention student survey (Appendix D). This information will be collected and organized and then compared to the results of the pre-intervention writing assessments and surveys. Trends in understanding of scientific explanation as well as comfort level in the ability of students to make claims, use evidence, and use reasoning will be examined. Student interviews (Appendix F) will also be conducted to gain insight into student attitudes towards the CER framework and the CER template.

DATA AND ANALYSIS

Data collection in this study included the results of student surveys, students' interviews, and a writing assessment both before and after the introduction of the CER template. The collection of this data aided in determining if the CER framework would affect student confidence in writing scientific claims, the frequency that claims were written, the frequency that data was used to support the claim, the frequency that reasoning was used, and the frequency that scientific principles were used in reasoning.

Based on survey questions and writing assessment scores, both student confidence in their ability to write claims and frequency of claim use in writing increased. Initial surveys from students indicated a wide range of explanations as to what a scientific claim is. When asked in the pre-intervention survey what a scientific claim was in their own words, student responses included, "A claim in the same as a hypothesis" and "A question that you are trying to prove true." Only 22% of students stated that a claim was a statement or argument that was being made.

When evaluating results of the Likert survey regarding student comfort level on ability to write claims before the intervention, a majority of students reported that they were comfortable or very comfortable with their ability to write claims. This percentage increased post-intervention. These results can be found in Table 2.

Table 2
Student Survey Results – Comfort Level in Claim Writing

	Pre-Intervention	Post-Intervention
1 - Not Comfortable	2.44%	4.88%
2 - Not Very Comfortable	7.32%	2.44%
3 - Somewhat Comfortable	36.59%	31.71%
4 - Comfortable	46.34%	43.90%
5 - Very Comfortable	7.32%	17.07%

Note. I am comfortable with my ability to write a claim in a scientific investigation (*N*=41).

Student performance with claim writing seems to coincide with student confidence in claim writing ability. The pre-intervention writing assessment mean sub-score for claim writing was 2.93 with a standard deviation of 1.37, while the post intervention writing assessment mean sub-score for claim was 3.63 with a standard deviation of 0.86. This represents a mean gain of 0.64. The difference between these pre- and post-test scores was statistically significant, $t(41)=2.5730$, $p=0.0119$. The results of the claim sub-score are shown in Figure 1.

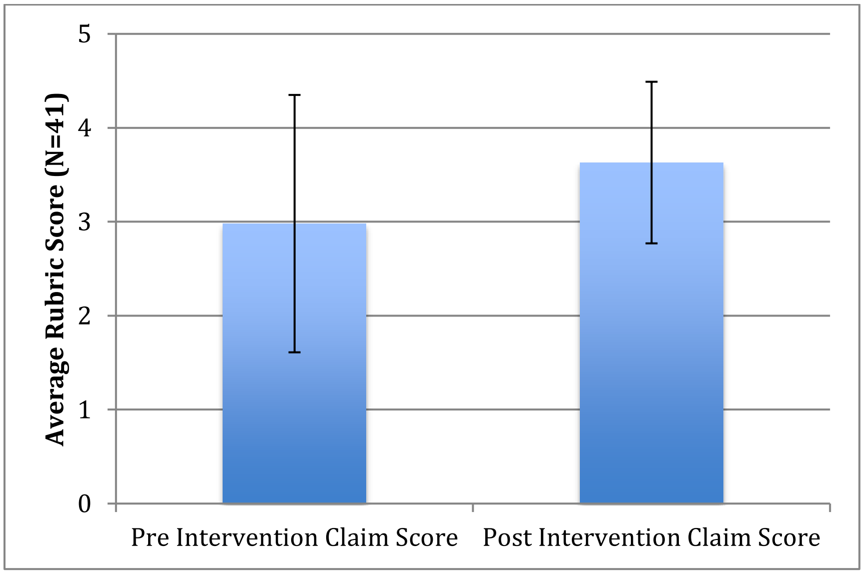

Figure 1. Comparison of the mean score of the claim component in the pre- and post-intervention writing assessment, (*N*=41).

Results related to student evidence use in a scientific claim did not reflect what was seen with claims. While both confidence and ability to write claims increased after the intervention, student confidence in using evidence decreased even though scores on the writing assessment increased.

When students were asked in the pre-intervention survey what a scientific explanation or claim should include, 49% of students mentioned that data or evidence should be included. When asked the same question in the port-intervention survey, 67% of students mentioned that data or evidence should be included in an explanation or claim. While the understanding that evidence was needed to back up a claim seemed to be more common among students, student confidence in their ability to use data decreased in the Likert survey. Before the intervention, about 66% of students ranked themselves as “comfortable” to “very comfortable”, while only 53.5% ranked themselves as such in the post-intervention survey. The Likert survey results for student confidence in ability to use data in scientific investigations are shown in Table 3.

Table 3
Student Survey Results – Comfort Level in Evidence Usage

	Pre Intervention	Post Intervention
1 - Not Comfortable	0.00%	4.88%
2 - Not Very Comfortable	7.32%	7.32%
3 - Somewhat Comfortable	26.83%	34.15%
4 - Comfortable	58.54%	41.46%
5 - Very Comfortable	7.32%	12.20%

Note. I am comfortable with my ability to use evidence to support my claim in a scientific investigation (*N*=41).

Despite a decrease in the lack of confidence in student ability to use evidence, students score significantly better on the evidence sub-score in the post-intervention writing assessment. The pre-intervention writing assessment mean sub-score for evidence writing was 2.07 with a standard deviation of 1.0, while the post intervention writing assessment mean sub-score for evidence was 2.93 with a standard deviation of 0.96. This represents a mean gain of 0.86. The difference between these pre- and post-test scores was statistically significant, t(41)=3.97, p=0.0002. The results of the evidence sub-score are shown below in Figure 2.

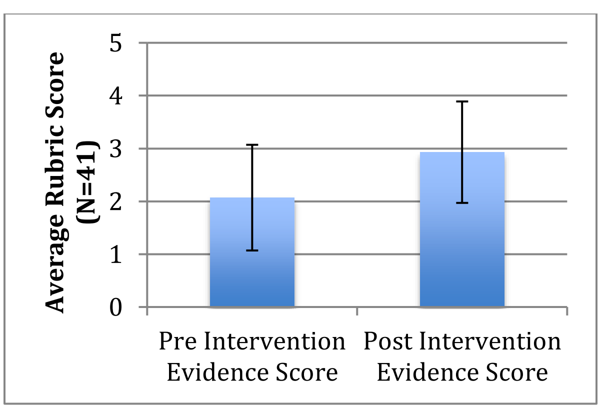

Figure 2. Comparison of the mean score of the evidence component in the pre- and post-intervention writing assessment, (*N*=41).

This increase in student use of evidence is also apparent when comparing the number of students who cited data in their pre-intervention writing assessment versus their post-intervention writing assessment. Scores on the rubric (Appendix B) of "1" and "2" indicate that no numerical data was cited, while a score of "3" or "4" indicates that a student cited numerical data that was provided. In the pre-intervention writing assessment, only 29% of students cited data that was provided, compared to the post-intervention writing assessment, where 71% of students cited data that was provided. These results are shown in Figure 3.

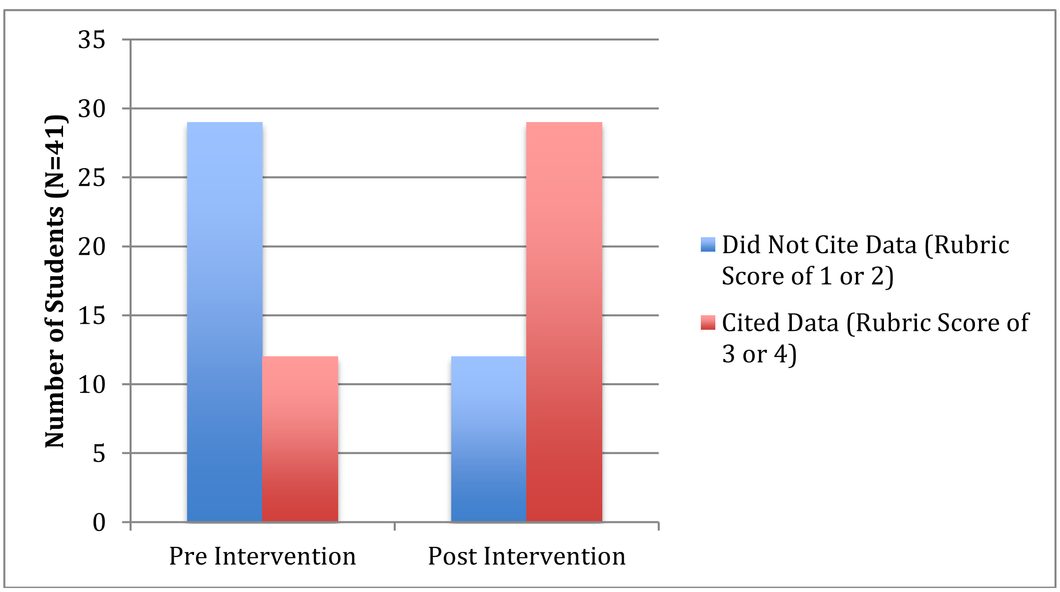

Figure 3. Comparison of the number of students that cited evidence in the pre- and post-intervention writing assessment, (*N*=41).

Student data related to reasoning indicated an increased understanding that reasoning was needed in their scientific explanations, however student use of reasoning showed a more modest increase when compared to changes in claim and evidence use after intervention. The data reflects a difficulty in student ability to use scientific principles in their reasoning.

Before the intervention, when asked what a scientific explanation or claim should include, 17% of students mentioned that reasoning should be included. This is compared to 41% post-intervention. While this shows an increase in the understanding of the importance of reasoning, student confidence in using it within their writing did not show a significant change. When asked what the most difficult part of writing a scientific explanation was, 27% of students mentioned that providing reasoning was most difficult. The Likert survey results for student confidence in ability to use reasoning in scientific investigations are shown in Table 4.

Table 4
Student Survey Results – Comfort Level in Reasoning Usage

	Pre Intervention	Post Intervention
1 - Not Comfortable	4.88%	4.88%
2 - Not Very Comfortable	4.88%	7.32%
3 - Somewhat Comfortable	46.34%	41.46%
4 - Comfortable	43.90%	31.71%
5 - Very Comfortable	0.00%	14.63%

Note. I am comfortable using reasoning that links evidence to my claim in a scientific investigation (*N*=41).

Scores on the reasoning sub-score on the writing assessment show an increase post-intervention. The mean sub-score for reasoning increased from 1.51 to 1.97, a gain of 0.46. The standard deviation for pre and post-intervention scores were 0.59 and 0.65, respectively. The different between these scores was statistically significant, t(41)=3.35, p=0.0012. The results for the reasoning sub-score and shown in Figure 4.

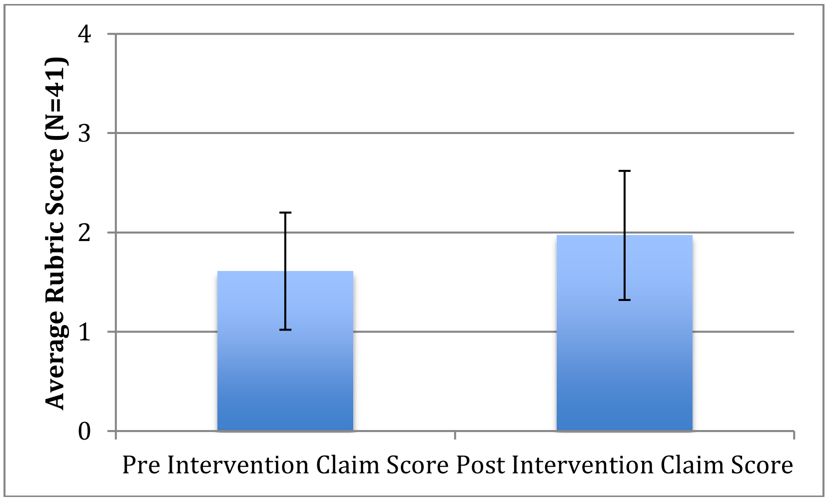

Figure 4. Comparison of the mean score of the reasoning component in the pre- and post-intervention writing assessment, (*N*=41).

Increases in reasoning scores were due to more students linking their evidence to their claims. In the post-intervention writing assessment, 80% of students were able to link their evidence to their original claim compared 46% before the intervention. These results are shown in Figure 5.

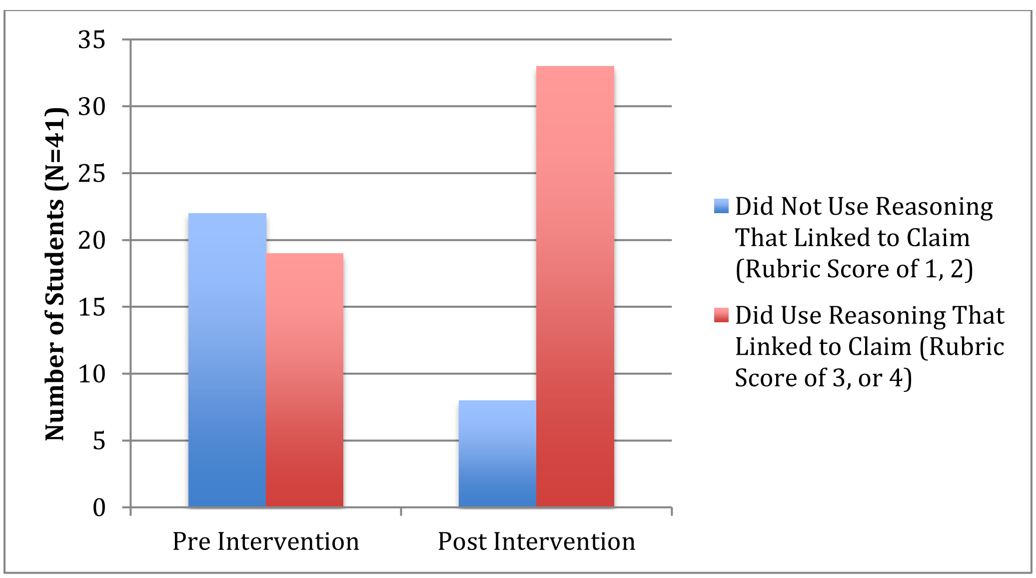

Figure 5. Comparison of the number of students that used reasoning that linked to their claim in the pre- and post-intervention writing assessment, (*N*=41).

Students did, however, show difficulty in using scientific principles in their reasoning. No students included scientific principles in their reasoning before the intervention and only one student was able to use scientific principles in their reasoning after the intervention.

INTERPRETATION AND CONCLUSION

My experiences with argumentative writing in the classroom reflect what I found in research regarding argumentative writing. While the skills related to argumentative writing are found in adopted standards in the NGSS, they were not part of my direct instruction until this research was performed. This is similar to previous findings related to argumentative writing (McNeill & Krajcik, n.d.).

When introducing the CER framework to students with the "Is a hot dog a sandwich?" discussion, I started to see the same struggles I discovered in my research in my own students. When students would say, "Of course a hot dog isn't a sandwich!" their responses when asked for an explanation as to "Why?" included statements like, "It just isn't" or "Just because." This reflects exactly the type of issues seen in research related to argumentative writing that exposed student weaknesses in their ability to use evidence and reasoning to help support their claims (Grymonpre, Cohn & Solomon, 2012).

To determine the effects of the direct instruction of the CER framework on conclusion writing in scientific investigations, answers to the original research questions must be answered and reflected upon. When evaluating how the CER framework affects the amount of times students write a claim when writing conclusions, the data indicated that students benefitted from the CER framework. Through direct instruction, students understood the importance of making a claim that acts as an answer to a research question rather than a question or a hypothesis as some students proposed before the intervention. The improvement in student claim writing was seen in the average rubric score from their writing assessment. Students also reported being more comfortable in their ability to write a claim after being introduced to the CER framework.

When evaluating whether the CER framework had an effect on the amount of times students used data in their arguments, it was clear that students improved in their ability to use quantitative data that was provided to them. Only 29% of students cited numbers before being introduced to the CER framework, reflective of similar studies in which 73% of students did not cite data within their claims. (Sandoval & Millwood, 2005) After using the CER framework, 71% of students were able to cite data that helped support their claim. There are still many students that lack the citation of any data, which resembles findings in similar research into argumentative writing, even at the college level. The increased use in evidence seen in this research is a major step in the right direction, however students seemed to lack confidence in their ability to use the evidence. According to Table 3, student surveys indicated that students were actually less comfortable in their ability to use evidence after the intervention. I believe that this is due to students having difficulty introducing the evidence in coherent sentences rather than an issue of what data to include. For example, students remarked that the most difficult part of writing a scientific explanation was "Putting the evidence into words" and "Giving the evidence" and "Writing the evidence down." When writing in class during the intervention, students used the sentence stems in the CER template (Appendix E), but did not have these sentence stems to use during the writing assessment. I think that further exposure to these stems, along with other claims that use similar wording will help students gain confidence in their ability to write in a more scientific style.

When evaluating student growth in the use of reasoning, it was clear that the CER framework helped students include reasoning more often. This growth is seen in Figure 5. It was apparent however, that students continue to struggle with using scientific principles in their reasoning. As noted in previous research cited in the conceptual framework, the reasoning component is the most difficult component in argumentative writing. Students were able to state why their evidence helped support their claim, but lacked any explanation as to why they got the data they did. This was reflected in student comments from the survey. When asked what the most difficult part of writing a scientific claim was, students responded, “Saying what the evidence means” and “Explaining my evidence”. Continued use of student models is needed, as recommended by literature regarding argumentative practices.(McNeill & Krajcik, 2008, p.125).

VALUE

I consider the analysis and creation of claims based on evidence and reasoning to be a crucial life skill. Evaluating and making claims involves critical thinking skills and encourages students to be skeptical of claims made by others. This skepticism can lead to further research and the search for what evidence actually shows. I believe that this process of evaluating claims is important in helping students better understand the scientific process, but more importantly, in evaluating claims in media that they are exposed to online and elsewhere. With the ubiquity of media in today’s society, it is becoming more difficult to determine what claims are rooted in evidence and what claims might be disingenuous. A skill that allows students to discern the difference between the two will help them become better-informed consumers and citizens.

This capstone research has increased my confidence in the CER framework to help students construct claims with evidence and reasoning, however I plan to implement the framework differently in the future. Based on my research, the CER framework helps students know what should be in their arguments and does increase their citation of evidence and their use of reasoning, but they continue to struggle with making connections to scientific principles or theories. In the future, I would like to introduce a new concept with an inquiry lab in which students seek to answer a research question and work on only a claim and evidence related to their claim. Then, after receiving formative feedback on their claims and covering new concepts related to biology, we could revisit the claim made earlier and add the reasoning component along with an explanation that includes links to scientific principles. I think that revisiting the data after learning new concepts will help students with the "Why did we get the data we did?" question. This approach to lab investigations also more closely follows an inquiry model in which students observe and experience phenomena before receiving instruction that explains phenomena.

For example, during our genetics unit, students investigate the effect of light on the production of chlorophyll in germinating tobacco seeds. Plants grown in the absence of light do not produce chlorophyll and are albino, while those are grown in light produce chlorophyll and are green in color. This lab could be performed before learning about genes, phenotypes, and the environment's effect on phenotype. Students would write a claim and provide evidence about light and how it affects chlorophyll production, but would leave out the reasoning part until we have learned more about the biology that explains why they collected the data that they did. After covering the biological principles that relate to genes and chlorophyll production, students would then complete the reasoning component of their lab. I believe that this approach will help students make the link between what we are learning in class and what they see in a lab setting.

The information that I have collected during this capstone project has shown me the value of reflecting on my own teaching strategies. This research experience has been encouraging in the sense that I have seen my interventions lead to measurable success, but my findings have also shown me that there is, and will always be, room for improvement. I look forward to incorporating more action research in my classes as a way to improve my own teaching practices.

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APPENDICES

APPENDIX A

CER TEMPLATE

Claim, Evidence, Reasoning and Constructing Scientific Explanations

Question: ____?

How to use CER

Answer questions scientifically by providing a claim, evidence, and reasoning

1. Claim	2. Evidence	3. Reasoning
State an answer to the question/prompt	Provide reliable information from experiments, facts, or a reliable source that supports the claim	Explains how the evidence supports the claim.
Helpful hints: Use key words and ideas from the question as you write your claim.	**Suggested sentence starters:** In the experiment… The data shows… According to the graph… One example from the experiment is… One piece of evidence is…	**Suggested sentence starters:** Based on this evidence, one must conclude __________ **because** __________ … The evidence is significant **because**… The evidence helps support my claim **because**…

YOUR TURN!

Claim: ____.

Your Pieces of Evidence:		Your reasoning:
Name the test/trial that was run.	What results did you get for that test/trial?	What does this evidence tell you? How can this evidence be used to support your claim?
1.	1.	1.
2.	2.	2.
3.	3.	3.

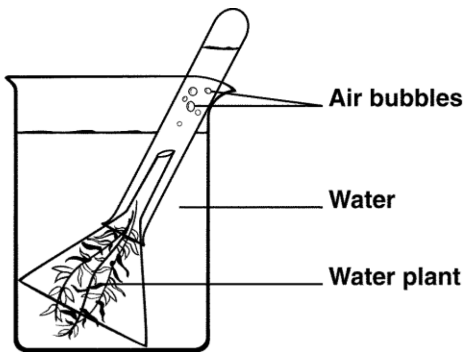
APPENDIX B

PRE AND POST-INTERVENTION WRITING ASSESSMENT

A biology student studying photosynthesis was asked the following question:

Does the type of light affect the rate of photosynthesis?

In order to answer the question, the student placed an aquatic plant in a beaker similar to the setup below. The student placed different lights over the plants and counted the number of oxygen bubbles released through photosynthesis by the plant each minute. The results of the experiment are shown below.



Light Type	**Oxygen Bubbles per Minute**
LED Light	27
Fluorescent light	24
Natural Light (outdoors)	35
Ultra Violet light	3

Use the data and information above to write a scientific explanation that answers the question: Does the type of light affect the rate of photosynthesis?

APPENDIX C

CER RUBRIC

CER Grading Rubric

	4	3	2	1
Claim	Claim is specific and directly answers question.	Claim answers question, but lacks clarity	Claim is vague or does not completely answer question	Inaccurate claim written or no claim written
Evidence	Several pieces of evidence are mentioned and actual data is included	Some evidence is mentioned and actual data are included. More evidence could be added.	Vague evidence mentioned (ex: NO ACTUAL numbers are mentioned)	No evidence mentioned
Reasoning	Uses reasoning for all pieces of evidence and relates data to scientific concepts	Uses reasoning for all pieces of evidence but does not relate data to scientific concepts	Uses reasoning for some, but not all, pieces of evidence and does not relate data to scientific concepts	Does not use reasoning to attach evidence to claim

APPENDIX D

PRE AND POST-INTERVENTION SURVEY

Answer the following questions honestly and to the best of your ability. This survey is entirely voluntary and will have no impact on your grade or success in this class.

1. In your own words, what is a scientific explanation or claim?

2. What should a scientific explanation or claim include?

3. What is the most difficult part of writing a scientific explanation or claim?

Use the scale to determine the number that best represents your own confidence on the specific question.

4. I am comfortable with my ability to write a claim in a scientific investigation (lab).

1	2	3	4	5
Not Comfortable		Somewhat Comfortable		Very Comfortable

5. I am comfortable in my ability to use evidence to support my claim in a scientific investigation (lab).

1	2	3	4	5
Not Comfortable		Somewhat Comfortable		Very Comfortable

6. I am comfortable in my ability to use reasoning that links my evidence to my claim in a scientific investigation (lab).

1	2	3	4	5
Not Comfortable		Somewhat Comfortable		Very Comfortable

7. I am comfortable in my ability to include concepts learned in class as part of my reasoning in a scientific investigation (lab).

1	2	3	4	5
Not Comfortable		Somewhat Comfortable		Very Comfortable

APPENDIX E

SAMPLE STUDENT CLAIMS

Evaluating CERs: Below is a sample CER conclusion that was written after performing the transpiration lab. The student had the following hypothesis: **If a plant is placed under light for 24 hours, then the amount of transpiration will increase.**

The Transpiration of Ivy Plants in Different Environments

	Day 1 Mass (g)	Day 2 Mass (g)	Day 3 Mass (g)	Day 4 Mass (g)	Day 5 Mass (g)	Mass Loss (g)
Control Plant	57.4	54.2	47.2	44.2	35.6	21.8
24-Hour Plant A	76.6	70.2	62.4	58.1	51.7	24.9
24-Hour Plant B	68.1	62.9	57.3	51.9	42.3	25.8

Claim
Evidence
Reasoning

If a plant is placed in 24-hour light, then plant transpiration increases. Plant A was placed under light for 24 hours and had a mass of 76.6g on day 1. After 5 days, its mass decreased to 51.7g. This is a mass loss of 24.9g. The control plant's mass changed from 57.4g to 35.6g after 5 days, which is only a mass of loss of 21.8g. Since Plant A lost more of its mass over the 5 days, the rate of transpiration increased under 24-hour light. Transpiration could have increased because the stomata were open all day since the plant was performing photosynthesis. Based on our data, out hypothesis that 24-light would increase transpiration was supported.

1-4 good

Sample A

The Good	Where Could It Improve?	Your Rating

Sample B

The Good	Where Could It Improve?	Your Rating

Sample C

The Good	Where Could It Improve?	Your Rating

FINAL CER CONCLUSION:

CLAIM:

As a result, plants in 24 hour sunlight have an increase on the rate of transpiration.

EVIDENCE 1 (Trial and results):

According to the results on day 3 the Ivy plant had already lost 11 grams, while the plant in normal sunlight lost 10 grams on the third day.

REASONING 1:

Based on this evidence one can conclude that transpiration works best in 24 hour sunlight, when the stomata is open.

EVIDENCE 2 (Trial and results):

Another piece of evidence is that in the final mass of my plant was 25.8 while control group was 21.8

REASONING 2:

This evidence helps support my claim because, if the transpiration works best or is increased in 24 hour sunlight it means that it loses more mass which it did.

EVIDENCE 3 (Trial and results):

The data shows that when we were meausuring the plants the plants cup had become more dry than it was before.

REASONING 3:

The evidence is significant because the process of transpiration is losing water and the cup was an example of the plant loosing water.

SUMMARY:

In conclusion, transpiration works best in 24 hour sunlight because the stomatas are guaranteed open which will make the plant loose water quick.

FINAL CER CONCLUSION:

CLAIM:

If a plant is placed under 24 hr light transpiration will increase.

EVIDENCE 1 (Trial and results):

To begin with I measured the plant for day 1 and the mass was 60.7.

REASONING 1:

The mass for the plant was higher in Day 1 than day 5.

EVIDENCE 2 (Trial and results):

Second off, I measured the plant for day 5 and the mass was 23.2

REASONING 2:

The mass for the plant was lower in Day 5

EVIDENCE 3 (Trial and results):

Lastly, I measured the plants change of mass and it was 37.5.

REASONING 3:

The plants change in mass for all the 5 days was 37.5

SUMMARY:

24-hour sunlight increases in transpiration

FINAL CER CONCLUSION:

CLAIM:

A windy environment will change the plant mass.

EVIDENCE 1 (Trial and results):

First of all, our experiment was to see the change in mass, in a different environment.

REASONING 1:

In a windy environment the mass decreased because it was not able to do transpiration.

EVIDENCE 2 (Trial and results):

Second of all, plant need water to grow, wise plants did not have water.

REASONING 2:

without water we already know the plant mass will decrease because it is not able to get the stuff it needs to grow.

EVIDENCE 3 (Trial and results):

Finally, The plant decreased its mass because it couldn't do Transpiration.

REASONING 3:

The plant couldnt do the stuff it need to grow, for example the water wasnt available in the plant so it didnt grow.

SUMMARY:

In conclusion, plant need certain environment to live and do transpiration

APPENDIX F

STUDENT INTERVIEW QUESTIONS

1. Did the use of the CER framework help you when writing scientific explanations? If so, what was most helpful?

2. Did you find the CER template helpful in organizing your thoughts before you wrote you explanations?

3. Did using the CER framework help you make connections between data in class and concepts that we learned in class?

4. Do you think the practice we did with CER will help you evaluate claims in other classes?