

EFFECTS OF THE CLAIMS-EVIDENCE-REASONING WRITING FRAMEWORK
ON TEACHING AND LEARNING IN EIGHTH GRADE SCIENCE

by

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Tanya Hobbs Long

July 2014

DEDICATION

I am dedicating this to my husband, Mark, and my two children, Brett and Emmy, who have sacrificed a clean house and many home cooked meals while I endured hours, months, and years working to obtain my masters. I could not have accomplished this without such a supportive, understanding and loving family.

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ABSTRACT

The need for instructing science students on writing evidence based explanations arises from the importance placed on this by the Common Core State Standards for college and career readiness. The Claims-Evidence-Reasoning (C-E-R) writing framework may be a means to this end. Explanations begin with a *claim* which makes an assertion or a conclusion about a question, problem, or observation. The *evidence* supports the claim using scientific data. The *reasoning* part of an explanation is used to justify that the students' evidence supports their claim, explains why the observations or data count as evidence of this claim by providing scientific principles. The framework was used with a variety of lesson types in astronomy and chemistry units. Students reported that the C-E-R framework helped them learn science content. The C-E-R framework also improved students' understanding of the nature of science.

INTRODUCTION AND BACKGROUND

Teaching Experience and School Background

This action research occurred during my second year teaching 8th grade science at Literacy First Charter School (LFCS). Prior to this, I taught 7th grade science for four years, in addition to various other teaching duties. Literacy First Charter school is located in El Cajon, California and was established 12 years ago. LFCS is a school of choice with high parent involvement within the school community. It has four campuses which encompass kindergarten through twelfth grade. During the course of this action research I was teaching at the Junior Academy campus which included fourth through eighth grades.

Student Demographics

The demographics of my students reflect the diverse cultures found in the east county of San Diego. I taught 124 eighth graders in four different class periods. Class sizes ranged from 28 to 32 students. There were a total of 68 girls and 54 boys. Sixty-seven percent of my students received free or reduced lunches. As shown in *Figure 1*, the major ethnicities of students include 43% white, 23% Hispanic, 20% Iraqi and 6% black.

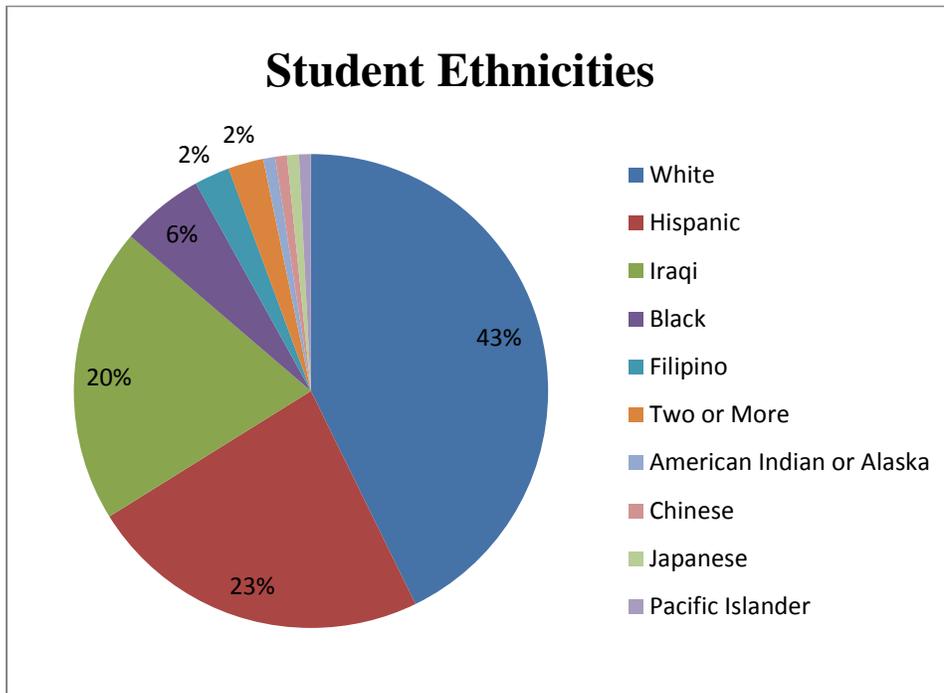


Figure 1. Student Ethnicities of 8th graders at LFCS, (N=124).

Figure 2 shows the diversity of second languages spoken in my students' homes. While 64% of my students were English only students, 36% had a language other than English spoken in their home. Chaldean, Spanish and Arabic are the main second languages spoken. Most of the Chaldean and Arabic speaking students' are immigrants from Iraq.

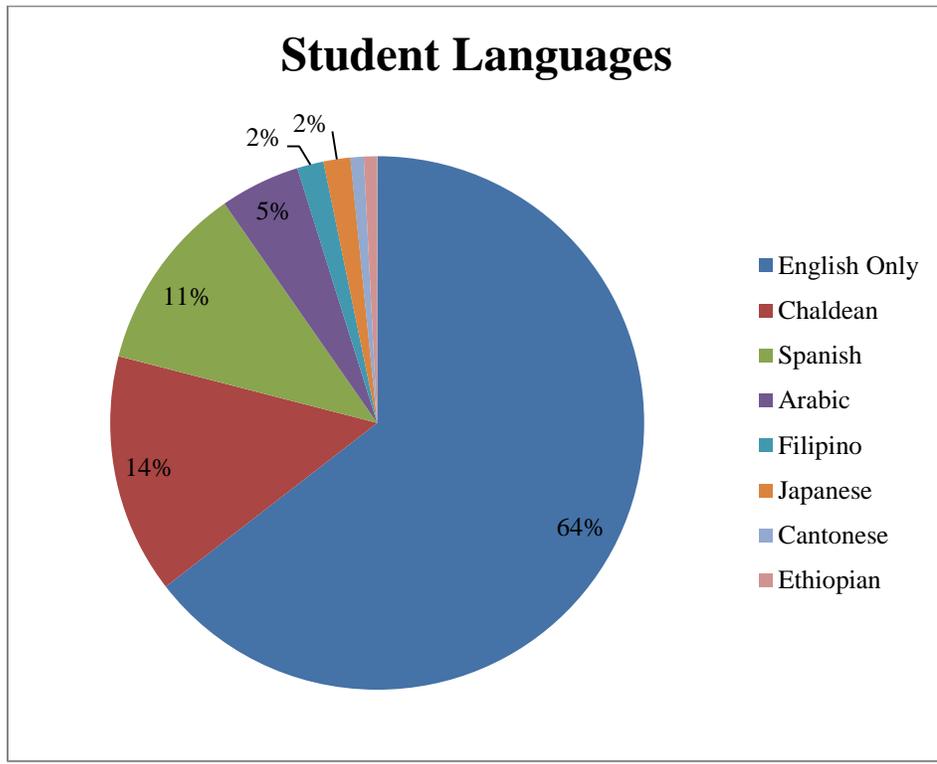


Figure 2. Student Languages of 8th Graders, (N=124).

Research Topic

The claims-evidence-reasoning writing framework is a scaffold that helps students- plural construct scientific explanations. The claim is a statement that answers a question or problem presented. The evidence provides support for the claim and may include textual evidence, evidence from graphs or tables as well as evidence from observations or data collected during student labs or teacher demonstrations. The reasoning is a justification of why the evidence counts as evidence and how it supports the claim using scientific principles.

I chose my research topic on the effects of the claims-evidence-reasoning (C-E-R) writing framework on teaching and learning in my science class as a means to transition to the Common Core State Standards (CCSS). In preparing for the CCSS, my school

administrators required that all teachers regularly integrate writing across the curriculum. Given the emphasis placed on argumentation in the language arts standards of the CCSS, the C-E-R framework, this seemed like a natural way to integrate writing within science in a meaningful way. Other science teachers at my school, as well as others, who are integrating writing within their science class to meet the needs of the CCSS, may also benefit from my action research.

Focus Question

What effects does the Claims-Evidence-Reasoning writing framework have on teaching and learning in an 8th grade science class?

Sub Questions

- How does the C-E-R framework apply to different types of lessons?
- How does the C-E-R framework impact students' content knowledge?
- How does the C-E-R framework affect student attitudes toward writing, thinking and learning, and the nature of science?
- How does using the C-E-R framework affect me as a teacher?

CONCEPTUAL FRAMEWORK

The need for an effective means to help students write evidence based explanations arises as a result of the newly adapted Common Core State Standards. "The Standards put particular emphasis on students' ability to write sound arguments on substantive topics and issues, as this ability is critical to college and career readiness" (National Governors Association Center for Best Practices, & Council of Chief State School Officers, 2010, p. 24). Given the need to include evidence based explanations, the question arises as to whether or not evidence based explanations occur naturally in

science classrooms. One past study used a systematic approach to analyze and score the quality of students' explanations in order to find out (Ruiz-Primo, Li, Tsai & Schneider, 2010). This study also compared the quality of students' written explanations to their scores on content knowledge assessments to find any correlation between the two. In other words, the central purpose of the study was to find out how well inquiry classrooms included opportunities for students to write scientific explanations and what impact this had on student learning. The key findings of this research were that only 18% (N=72) of students gave complete scientific explanations to include all three necessary components (i.e. a claim, evidence, and reasoning). Forty percent of students had a claim only, without any evidence or reasoning. About 12% had claims with supporting evidence, but no reasoning. Explanations that were incomplete also correlated to explanations with an incorrect claim or a claim that did not relate to the objective of the lesson. The implication is that fragmented explanations do not support and may even impede the learning goals. On the other hand, a positive correlation existed between the quality of students' explanations and students' scores on end of unit tests, particularly on open-ended questions. To summarize, writing complete evidence-based explanations may help students learn content knowledge, yet students are not naturally writing quality explanations in those classrooms. This identifies the need for action research to determine effective strategies to help students write evidence based explanations.

Another purpose for writing evidence based explanations is that doing so may develop students' understanding of the nature of science. An investigation of the relationship of high school students' argumentation skills and their understanding of the nature of science revealed a strong correlation, particularly in terms of their ability to

write a counter argument (Khishfe, 2012). In a study with 219 eleventh graders in five schools in Beirut, Lebanon, students answered a questionnaire pertaining to two controversial scenarios; genetically modified foods and fluoride in drinking water. Students were first asked to write an argument, counterargument, and a rebuttal with justification. Secondly, students answered questions regarding the nature of science in terms of the tentative, empirical, and subjective aspects of science. Results showed that fewer than 20% of the high school students could write all components of the argument with more than one reason for the scenario of genetically modified foods. Forty-six percent of the students demonstrated understanding of the subjective aspect of science, but most students showed naïve views regarding the tentative and empirical aspects of science. Analysis revealed students who could write an effective counterargument strongly correlated to those who also demonstrated a stronger understanding of the nature of science. Khishfe suggests that teaching students how to write counterarguments makes them more aware of other viewpoints which helps them understand the subjective nature of science (2012). The context in which students are writing about can also affect the quality of their argument, revealing the importance of choosing topics that are relevant and engaging to the student. When set within meaningful contexts, the implications are that teaching students to write arguments can help them understand more fully the nature of science.

In addition to writing one's own explanation, a persons' ability to evaluate the explanations of others is part of being scientifically literate. Students' today are saturated in media from a variety of sources. The skill of evaluating the validity of scientific claims is an important skill for students to develop. Yet, a recent study of first year college

students in Australia indicates no more than 50% can critically evaluate scientific claims in the popular press (Murcia, 2009). In this study, 130 college students answered a questionnaire created to test their scientific literacy by answering four questions regarding a news brief. The students' answers were categorized on a six point scale determining their level of critical evaluation of the news report. Answers of a critical nature were: evaluating and challenging. Answers of an uncritical nature included deference, affirmation and dominating, as well as echoing. A seventh scale was added to include off task responses. Overall, 46% of the college freshmen were uncritical and accepting of the news article claim without evaluating the evidence or other factors such as possible bias or methods of the researchers. Ten percent were off task, meaning they did not even respond to the science information of the article, leaving only 44% that critically interacted with the content of the scientific claim in the news brief. The results of this study indicate direct teaching with appropriate scaffolds is needed to help students learn to evaluate scientific news (Murcia, 2009).

To address the problem of how to assist students in making scientific explanations in which they defend their claims using relevant evidence and reasoning, certain findings provide direction. Specifically, an investigation of context-specific language of scaffolds vs. generic language scaffolds was particularly helpful (McNeill & Krajcik, 2009). This study not only looked at two different types of scaffolds, but also teacher instructional practices and how the interaction between the two supports student learning of science content and scientific explanations. Over an 8-week period six middle school teachers implemented the same chemistry curriculum. The six teachers came from different schools in the Midwest of the United States. There were a total of 568 students in the

study. During the treatment, there were 13 opportunities in which students were asked to write scientific explanations. For the design of the study, each teacher taught some classes using context-specific curricular prompts and other classes using a generic-explanation scaffold. The context-specific curricular prompts provided hints about how to apply the content knowledge to the particular context to write a scientific explanation. The generic-explanation scaffold used a claim, evidence, and reasoning framework. The claim is “an assertion or conclusion about a question or problem. Evidence is the scientific data that needs to be both appropriate and sufficient to support the claim...The reasoning is a justification for why the data counts as evidence to support the claim, which often includes appropriate scientific principles” (McNeill & Krajcik, 2009, p. 420).

Results showed that the context-specific curricular scaffold was more effective in terms of helping students to write scientific explanations and learn the science content as demonstrated on multiple-choice questions. However, another pattern revealed the importance of how the teacher defines scientific explanation. The three teachers who used the language of the framework; claims, evidence, and reasoning, consistent with the intentions of the study, had students write better explanations using the context specific scaffolds. On the contrary, for the two teachers who modified the definition of a scientific explanation (by simplifying the reasoning to a definition) or the one teacher who did not use the treatment, neither the context-specific nor the generic scaffolds proved more effective. This goes to show the role of the teacher and the type of scaffolding used both play an important part in the quality of students’ explanations (McNeill & Krajcik, 2009).

When teaching students to write explanations it is important to know that explanations in science cannot be separated from the purpose of argumentation. A

scientific explanation includes three goals; sensemaking, articulation, and persuading arguments (Berland & Reiser, 2009). The first goal of this framework means students are interpreting the evidence from an investigation, data table, or graph. The second goal of articulation requires students to explain what or why an event occurred. The third goal of persuasion asks students to engage in the social interaction of coming to a consensus within the classroom community. Put another way, the goals of explanations are to construct, present, and debate. With these three goals in mind, analysis of 92 student explanations revealed two different ways in which students constructed explanations. First, some students did not explicitly break their explanation into the three parts of a claim, evidence and reasoning. Instead, these students intermixed the claims, evidence, and reasoning in a way that made it difficult for the reader to distinguish between the students' evidence and inferences. This embedded style accounted for 45% of the student explanations and implied that students did not understand the persuasive goal of the scientific explanation. The second style clearly delineated the claim, evidence and reasoning which made it easier for an audience unfamiliar with the data to understand the evidence and reasoning. Forty six percent of students organized their explanations in this way. The implication of this style is that these students were aware of the need to communicate to an audience unfamiliar with the data, which showed these students had an understanding of the purpose of persuasion in a scientific explanation.

Two strategies have been suggested to help students understand the persuasive goal of any scientific explanation: One; teach students to explicitly cite the data by using sentence stems that name the evidence source or generally reference the evidence. Two; present the data in the same way it is presented in the original data (Berland & Reiser,

2009). Understanding the three goals of explanations; sensemaking, articulating and persuading and knowing that persuading is students' weakest area, the above strategies are important to teach students when using a claims, evidence, and reasoning writing framework for scientific explanations.

When implementing the Claims-Evidence-Reasoning framework as part of my treatment it was recommended to include the following five strategies. "Make the framework explicit, model and critique explanations, provide a rationale for creating explanations, connect to everyday explanations, and finally, assess and provide feedback to students" (McNeill & Krajcik, 2008, p. 125). It cannot be assumed that students know how to write explanations, therefore directly introducing and defining the three parts of an explanation; claim, evidence, and reasoning, is necessary. Next, is to show students good examples of written explanations as models, pointing out the strengths. Then use weak examples to critique in a class discussion. Another strategy is to explain why explanations are important in science. Two reasons are suggested. The first reason is that it is the nature of science to explain the natural world. The second reason is to persuade others. An additional strategy is to provide an everyday example, such as a claim regarding why a popular band is "the best band ever", and have a class discussion to evaluate the quality of the explanation. This puts the explanation into an understandable context which is important for students to form effective arguments (Khishfe, 2012). A final strategy is to give students specific feedback in terms of the components of their explanations and the science content. Offer suggestions for improvement by asking probing questions to get students to think deeper about the content. Then, give students an opportunity to make revisions from this feedback.

Another effective strategy in supporting students in writing scientific explanations was to use context-specific scaffolds within the more general categories of claims, evidence, and reasoning (McNeill & Krajcik, 2009). By providing specific probing questions for each, this prompts students to look for specific evidences to ensure they choose evidence that is both relevant and adequate. To help students understand the persuasive goal of a scientific explanation another strategy is to teach students to explicitly cite the data and to present the data in the same way it is presented in the original data (Berland & Reiser, 2009). Providing students with sentence starters helps structure the language to cite the data which will allow an unfamiliar reader to know what they are referencing.

A strategy to help students evaluate the claims and evidence of scientific news articles is a modified Line of Reasoning “MoLOR” model (Ford, 1998). This model gives a procedure for students to use to evaluate scientific news in the popular press. This begins with identifying the claim, listing the evidence cited in the article, and then evaluating the evidence. Evaluation of the evidence is to decide if the evidence is empirical, from a scientific source and bias free. The claim may then be accepted tentatively, accepted conditionally or rejected. If the evidence is sufficient and presented with reasoning, it may be accepted tentatively. If the evidence is minimal but still reasonable, it can be accepted conditionally. If evidence is lacking or illogically presented, the claim is rejected. Students then write a critique of the science news article. With this procedural model, students develop scientific reasoning, instead of using opinion or prior knowledge, to evaluate scientific claims, evidence and reasoning.

A research-based assessment rubric had been developed for use in analyzing students' scientific explanations which I used in my action research (Harris, McNeill, Lizotte, Marx, & Krajcik, 2006). In a seventh grade class with an experienced science teacher, base and specific rubrics were researched to determine their effectiveness in assessing student learning in writing scientific explanations. Thirty-two students participated in this midwestern school of primarily African American students, nearly all of which received free or reduced lunches. Pre and post tests were given which included 20 multiple choice questions and four open-ended questions. It was the open-ended questions that were evaluated using the rubrics. Student artifacts, such as writing samples were collected during the treatment and evaluated using the rubrics. To determine the effectiveness of the rubrics, three raters scored students' work using the rubrics and were found to be in agreement 91% of the time regarding the level scores. Through the course of this study, researchers found the base rubric and the specific rubrics to be effective tools in analyzing student learning. By breaking a scientific explanation into the three parts; claims, evidence, and reasoning, researchers were able to determine that students began with strong skills in making claims, made growth in providing evidence, but did not make as much progress in writing their reasoning. The researchers concluded the base-explanation rubric can be used by teachers or other researchers to tailor fit a particular unit of study. Since the C-E-R base rubric was demonstrated to be an effective tool, I used their base rubric as part of my data analysis of student explanations, as well as, a means to provide feedback to students.

METHODOLOGY

Treatment

For my action research project, I implemented and used the claims, evidence, and reasoning framework to instruct students in the necessary components of a sound scientific explanation. As a baseline to compare how effectively students write evidence based explanations prior to the treatment, I used a writing sample I collected from students in September. In this previous lesson, students engaged in a lab in which they modeled the sun, earth, and moon to determine the cause of moon phases. In this pre-treatment part of my study, students were asked to write an explanation with supporting evidence from the lab without being introduced to the framework. Responses were then scored by the teacher using a rubric developed for the C-E-R framework.

To begin the treatment period, students were introduced to the C-E-R framework. To first teach the C-E-R framework, I used everyday examples. Students wrote their first C-E-R to support an everyday example such as who they thought was the best band, sports team, video game, etc... Students used laptops to search for evidence to support their claim and used the C-E-R framework to structure their writing. Sentence stems were also provided as examples on how to start sentences for claims, evidence and reasoning sentences. The following day, students were then placed in groups to share their writing to select which students wrote the most convincing explanation.

Students' first scientific application of the framework occurred during Chapter 1 on the Earth, Moon and Sun. Students evaluated one of four theories of the moon's formation. In groups of four, students read about fourteen pieces of evidence and then determined if it supported, refuted, or was uncertain for one theory of the moon's origin.

Students then evaluated whether that theory was a likely or unlikely explanation of the moon's origin and choose four evidences to best support their claim. Students then wrote an explanation using the framework and provided sentence stems. This was the first and only instructional use of the C-E-R framework during chapter 1. To conclude this chapter, students were assessed with both multiple choice questions as well as four open ended written questions.

The next opportunities to use the C-E-R came with the next chapter on the solar system. During this chapter students used the framework. Students learned about the structures of the sun. Students were presented with the question, "What is the relationship between sunspots and magnetic storms on Earth?" A graph of the annual number of days with magnetic storms on Earth was provided as well as a data table with the annual number of sunspots. Students created a graph using the sunspot data in order to visually compare the two sets of data. To help students answer the question, I guided students to list the years which represented maximum and minimum numbers of sunspots and then compared these to the maximum or minimum number of magnetic storm days. As a class, I guided students to list these using a t-chart, which is a chart designed to look for patterns between two variables. I then asked students to write a claim to explain the relationship between the number of annual sunspots and the number of annual magnet storms on Earth.

In the same lesson, the rubric, shown in *Table 1*, was introduced to students for the first time to explain how each component of an explanation would be evaluated. We discussed the terms *appropriate* and *sufficient*. I had students add in specifics on the base rubric, such as providing at least three years as evidence to show the pattern. Students

were also introduced to the idea on the rubric that the reasoning should include scientific principles. We reviewed what they had previously learned about sunspots and solar flares and discussed the connection this may have to magnetic storms on Earth. Students added to the rubric that the reasoning should explain the relationship between these. After the writing task was complete on the following class period, students' peers assessed their writing using the rubric.

Table 1
Base Explanation Rubric

Component	Level		
	1	2	3
<i>Claim</i> An assertion or conclusion that answers the original question	Does not make a claim, or makes an inaccurate claim.	Makes an accurate but incomplete claim.	Makes an accurate and complete claim.
<i>Evidence</i> Scientific data that supports the claim. The data needs to be appropriate and sufficient to support the claim.	Does not provide evidence, or only provides inappropriate evidence (evidence that does not support claim).	Provides appropriate, but insufficient evidence to support claim. May include some inappropriate evidence.	Provides appropriate and sufficient evidence to support claim.
<i>Reasoning</i> A justification that links the claim and evidence and shows why the data count as evidence by using the appropriate and sufficient scientific principles.	Does not provide reasoning, or only provides reasoning that does not link evidence to claim.	Provides reasoning that links the claim and evidence. Repeats the evidence and/or includes some scientific principles, but not sufficient.	Provides reasoning that links evidence to claim. Includes appropriate and sufficient scientific principles.

The next opportunity to implement the C-E-R framework introduced students to using the framework using data they collected from a lab as opposed to data provided previously from text, graphs, or tables. In this lab, students used a model to simulate the

effect of a planet's distance from the sun to the length of its period of revolution. The model simulated the force of gravity using a string with a washer threaded through a rigid plastic tube and a plastic washer on the other end. Holding the plastic tube, students swung the string with just enough force to keep it moving in a circular path. They varied the length of the string and timed the period of ten revolutions using a stop watch. Using the data, students had to make a claim as to how the distance affected the period of revolution. This time, they used data they had collected as their evidence. I then referred them to scientific principles from class notes and the textbook to include in their reasoning.

The following C-E-R lesson used the framework as a means to discuss and evaluate the legitimacy of claims in two different current events news articles. Using both articles, which made claims about the possibility of life beyond Earth, students identified the claims, evidence, and reasoning presented in the articles as well as discussed the credibility and biases of the experts and sources. In the first article, *Mexican Government Releases Proof of E.T.s and Ancient Space Travel* (Ambellas, 1) students were presented with evidence of new interpretations of ancient Mayan codices as images depicting alien contact. In contrast, the news article, *NASA Curiosity Rover Discovers Evidence of Freshwater Mars Lake* (Achenbach, 1) presented recent evidence of soil samples from the Curiosity Rover to support the claim that ancient Martian lakes once contained fresh "drinkable" water in which microscopic life could arise and exist. While I had intended to have students write an evaluation of the claims, evidence and reasoning in the two articles, the timing of winter break did not allow this possibility. However, using the framework as a means of reading and discussing was a rich activity.

To summarize, during the Chapter 3 study of the solar system, students used the C-E-R for three different lessons over the course of five weeks. They first used evidence provided in a graph and a table to support their claim about the relationship between solar storms and magnetic storms on Earth using scientific principles presented in class notes and the textbook. They next applied the framework to evidence they gathered from a lab while using a model to simulate how distance from the sun affects a planet's period of revolution. To finish chapter 3, students read and evaluated the claims, evidence and reasoning regarding life beyond Earth using two different current event news articles and then participating in a class discussion. Following the chapter, students were tested with multiple choice questions as well as four open-ended writing questions.

In the next chapter, Chapter 4: Stars, Galaxies, and the Universe, I did not include any lessons which used the C-E-R framework. The purpose was to then evaluate how well students would still be able to apply the framework on test questions. Three of the four questions were specifically tailored to fit the C.E.R. framework.

Following the conclusion of our studies in astronomy, I then began the first chapter in chemistry with Chapter 1: Introduction to Matter. During the unit, I incorporated a lab from the FOSS: Chemical Interactions curriculum called "Mystery Mixture." During this lab, students observed the physical and chemical properties of nine different compounds to determine the two compounds found in the Mystery Mixture. Following the conclusion of the lab, students wrote a paragraph using C-E-R in which they provided their evidence and reasoning to support their claim as to the ingredients of the Mystery Mixture. At the conclusion of this chemistry chapter students took a test which included both multiple choice questions as well as four open-ended writing

questions. Three of the four open-ended questions were specifically written to assess students' application of framework.

To assess student retention of the framework once more in March, students were asked to write an explanation of a material known as "Oobleck." Following lessons on the states of matter, students investigated a material made from a mixture of water and corn starch. This non-Newtonian fluid is difficult for students to classify as a liquid or a solid since it responds to pressure by behaving as a solid momentarily. The intention of the lab was for students to apply their knowledge of the defining properties of solids and liquids to classify the Oobleck but to also apply their knowledge of the arrangement and motion of the particles to explain seemingly contradictory behavior of this substance. Following their time to explore and play with the Oobleck, students were asked to write an explanation to answer the question, "What is the state of matter of Oobleck?" Students were instructed to include scientific principles to explain what happens to the arrangement of the particles in Oobleck to account for its strange behavior.

To summarize the methodology, during the treatment period of four months, October through February, students were asked to write scientific explanations as class assignments six times and formally assessed on chapter tests four times. After collecting a pretreatment explanation of moon phases, students were introduced to the framework using a non-science topic. Students then applied the C-E-R framework to their first science topic on the origins of the moon. They continued practicing the C-E-R framework with the topics of solar storms and a planet's period of revolution. Following the final astronomy chapter in which the framework was not used during instruction, students used the framework with a chemistry unit to conclude the "Mystery Mixture" lab. Following a

lab on the states of matter in March, students were asked to write an explanation using C-E-R in order to assess their retention of the framework once more.

Instruments

To assess the effects of the treatment in which the C-E-R framework is implemented, I used several instruments. I collected data using a student Likert Survey, student interviews, chapter tests, student writing samples, a C-E-R rubric, and a field observations journal. Table 3 specifies which instruments provide data for each research question.

Table 2
Triangulation of Data

DATA COLLECTION MATRIX	Student survey	Student interviews	Chapter tests	Student writing samples	Field observations
Focus question How does a C-E-R framework affect learning and teaching in an 8 th grade science class?	X	X	X	X	X
How well does a C-E-R framework apply to different types of lessons?				X	X
How will using the C-E-R framework impact students' content knowledge?			X	X	
How will the C-E-R framework affect student attitudes toward writing in science, thinking and learning in science, and the nature of science?	X	X			X
How will using the C-E-R framework affect me as a teacher?	X	X			X

Student Survey

The Likert Survey, with select open ended questions, assessed students' attitudes toward writing, thinking, learning, science, and the nature of science. This survey was given prior to the treatment and again at the end of the treatment. The entire survey can be found in Appendix A. Questions from surveys found at the *Online Evaluation Resource Library* (2013) served as models for this Likert survey. Specifically, some questions on my survey were modified from three different instruments developed for *Course, Curriculum, and Laboratory Improvement (CCLI)* (2013) and *Innovative Technology Experience for Students and Teachers (ITEST)* (2013) and *Computer Applications to Enhance Inquiry-Oriented Library Instruction in Biology at a 2-Year College* (2013). While the goals of these surveys ranged from assessing students' attitudes and beliefs in mathematics, science, or technology, I was able to use select questions and modify these as needed for my specific purpose of assessing my students' attitudes about science and writing. By using the wording or select questions developed by prior researchers helps to ensure the validity of the data I gathered.

Chapter Tests

The chapter tests assessed student content knowledge. These tests, created using a test bank, included multiple choice questions, fill in the blank questions, and paragraph length essay questions. Open ended essay questions on tests included questions designed to assess content learned without using the C-E-R framework as well as questions to assess content learned through use of the C-E-R framework. The scientific explanation rubric was used to quantify progress in students' writing. The rubric (see table 3) also

provided a means to give students specific feedback on the quality of their explanations. In total, students completed four chapter assessments from October through March.

Student Writing Samples

In addition to tests, student writing samples completed as part of the treatment were collected and scored using the rubric. The writing samples of nine students, selected using random stratified sampling, were used to assess any changes in the quality of students' scientific explanations prior to and during the course of the treatment period.

Student Interviews

A fourth instrument, student interviews, gathered data to answer the following sub questions. "How will the C-E-R framework affect student attitudes toward writing and learning in science?" and "How will using the C-E-R framework impact students' content knowledge?" Interviews of eighteen students took place near the middle of the treatment period in December. I applied for and was granted exemption from the Institutional Review Board at Montana State University for use of both student interviews and student survey (See Appendix B).

Sampling Strategies

I had 124 eighth grade science students in four different class periods. I used different sampling strategies for different instruments. For the student survey, I collected and analyzed data from all students. For the student interviews, analysis of student work samples and rubric scores, I used stratified random sampling. Student names were grouped into low, average and high lists and then randomized for selection. For the student work samples, I collected and evaluated six low performing, average performing, and high performing students for a total of eighteen. Whenever possible, artifacts from

these same students were evaluated each time the framework was used to allow for a qualitative evaluation of changes in students' written explanations over time. Each of these written artifacts was scored using the rubric to provide quantitative data. Hard copies of written samples were filed as well as scanned and stored digitally on my Dropbox account.

I also used stratified random sampling to select nine students to interview. Randomly selected students included three low performing, three average performing, and three high performing students. Notes were taken of student answers during the interview and later transcribed. Hard copies of transcriptions were filled as well as digitally stored in my Dropbox. Qualitative analysis included summarizing the general trends in responses and using quotes to exemplify typical student attitudes. Additionally, quotes were sorted into groups with similar responses and tallied to quantitatively report the occurrence of various attitudes by students regarding use of the C-E-R framework.

In summary, the methodology included a treatment period in which the C-E-R framework was initially taught using a non-science topic, then applied to science topics in astronomy and chemistry. The C-E-R base rubric was used to introduce the necessary components of a scientific argument, as well as, provide feedback to students. Instruments included a student Likert Survey, student interviews, chapter tests, student writing samples, and field observations journal. Sampling strategies included sampling all students for the Likert Survey. Stratified random sampling was used to assess writing samples and student interviews. Data collected was used to answer the research questions of how the C-E-R framework affected students' learning of content knowledge, attitudes,

toward writing, learning, thinking and the nature of science, as well as the effect of my teaching practice.

DATA AND ANALYSIS

Effects on Student Attitudes

To assess the effect of writing scientific explanations using the C-E-R framework on student attitudes toward science, I collected data using a Likert survey with open ended questions. On the Likert survey, students were given four choices on a scale with 1 being “strongly agree” and 4 being “strongly disagree.” Once the results were gathered, these answers were quantified in the following way. The frequency of each choice of the Likert survey was tallied and taken as a percentage of the total. If the statement was negatively stated, such as “Science is boring and dull” the strongly agree was scored a 1 and the strongly disagree was scored a 4. If the statement was positively worded, such as “I like science,” strongly agree was scored a 4 and strongly disagree was scored a 1. In this way, the higher numerical score corresponds with a more positive attitude. Assigning a number value to these responses allowed for a tally of the frequency of “most positive”, “positive,” “negative,” and “most negative” attitudes. When the survey was given again at the end of the treatment, the frequencies were then compared to determine any overall changes in attitudes. The frequencies were reported as a percentage of the total to adjust for slight differences in the total number of students taking the pre and post survey. When the survey was given, students were notified that their school email address, which contains their name, would be automatically captured by the Google form.

The Likert questions were grouped into the following categories; Nature of science, attitudes toward science, attitudes toward thinking and learning, and attitudes toward writing. However, for this analysis, I did not include the results from one question included on the survey, “Most scientific claims are educated guesses.” I felt that since many elementary teachers present scientific theories and hypothesis with this wording, I may not be truly assessing whether students understand the difference between an educated guess and claims that are supported with evidence. I did however, still include this question on my final survey and will report any relevant changes in later analysis if there are any noteworthy changes. Table 4 lists the questions grouped into each category.

Table 3
Categories and Questions from Likert Survey

Nature of Science	<i>Science is essentially an accumulation of facts to be memorized.</i> <i>Science is essentially about explaining the world around us.</i> <i>Science is actually based on the best available evidence at the time; it may change with new evidence.</i> <i>Trustworthy scientific claims are supported with evidence and reasoning.</i>
Attitudes Toward Science	<i>I am good at science.</i> <i>I enjoy learning science</i> <i>Science is dull and boring.</i> <i>Science is more interesting than most school subjects.</i>
Attitudes toward Writing	<i>I like writing.</i> <i>I am good at writing.</i> <i>Writing in science class helps me to understand science better.</i>
Attitudes Toward Thinking & Learning	<i>I can think like a scientist.</i> <i>Science helps me become a better critical thinker.</i> <i>Explaining scientific ideas helps me understand them better.</i>

Attitudes Toward the Nature of Science

Four questions on the survey were designed to assess students' attitudes toward the nature of science. The frequencies of responses to these questions were corresponded to positive and negative attitudes. Strong agreement with a negative statement such as "Science is essentially an accumulation of facts to be memorized" was corresponded to the most negative student attitude. Strong agreement with a positive statement such as "Science is essentially about explaining the natural world" was corresponded to the most positive student attitude.

The results of students' positive versus negative attitudes are graphed in Figure 3. Regarding the nature of science, 72% of student appropriately agreed or disagreed with statements regarding the nature of science prior to the treatment period. This was the strongest score of any category to begin with. The strong initial scores regarding the nature of science may have been due to the emphasis placed on this in their 7th grade science program. Having taught seventh grade science for four years prior to moving to 8th grade, I implemented a strong foundation in teaching the nature of science as part of the 7th grade curriculum.

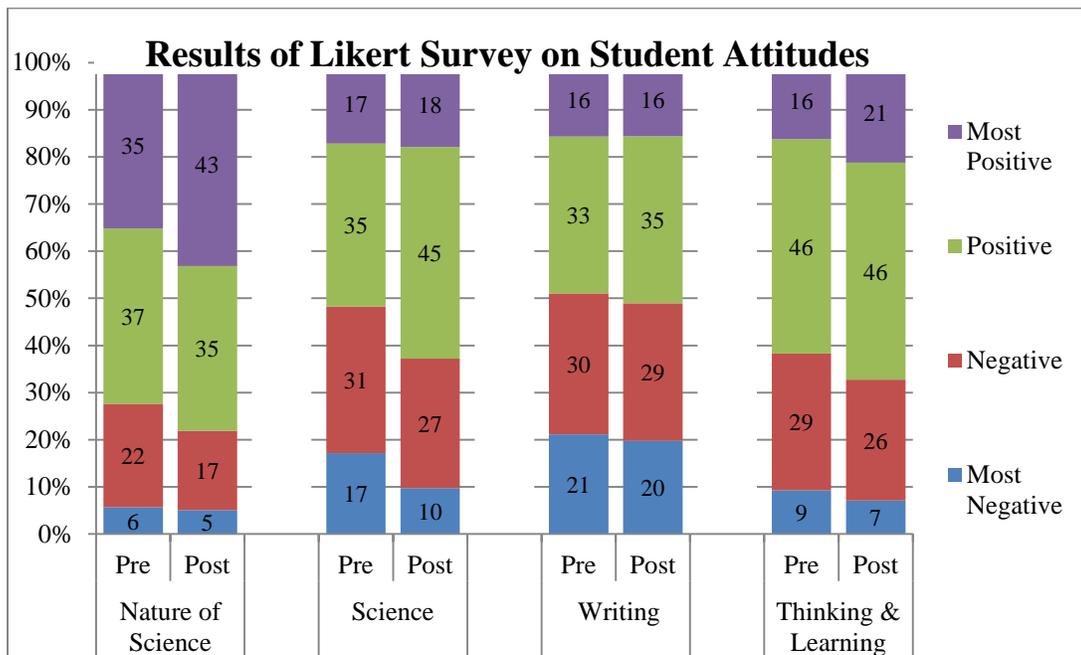


Figure 3. Percentage of Student Attitudes, ($N=115$ pre & $N=113$ post).

Following the treatment period students' attitudes toward the nature of science improved (figure 3). The most positive category improved the most going from 35% to 43%, an 8% increase. Overall, when combining the positive with most positive and the negative with most negative, the overall positive attitudes improved from 72% to 78%, a 6% increase overall. In my journal, I noted how using the C-E-R framework helped me focus on evidence and instruct students in the nature of science. Focusing on the nature of science is particularly helpful since a large majority of my students come from conservative Christian families, who do not always accept scientific theories which they perceive as conflicting with their religious views. When writing our first C-E-R using a science topic, the theories of the moon's formation gave me an opportunity to address the nature of science. "A student... asked me what she should write because she doesn't believe any of these theories because she is a Christian. I instructed her to look at the

evidence and decided if the evidence supports or refutes that theory. I told her that it was okay if she believed something different, but that in science, we have to look at the scientific evidence from the natural world to support or refute claims. I addressed this with the class as a whole, reminding them that science is about explaining the natural world using only evidence that we observe and measure from nature. I said that for this reason, they could not, for example, use the Bible as evidence against or for a [scientific] theory.” I found that use of the framework helped focus instruction on evidence which was reflected in the gain in students’ positive attitudes toward the nature of science.

Attitudes Toward Science

Another focus of my action research was to assess how use of the C-E-R framework affected students’ attitudes toward science. Before the treatment period, only 52% of students had a positive or most positive attitude toward science (figure 3). To identify the possible causes of this low percentage of positive attitudes toward science, I followed up with a second brief survey. One student responded, “Science [this school year] is way different now and that's good. We have more uses for the computers. Science is more interactive and new. It’s not unit after unit after unit...Last year I felt like it was Cornell notes every day.” Other students mentioned the lack of experiments done last year in science as a cause of negative attitudes toward science, “I think it had to do with science class in previous years because the only thing we did [was] to remember things that were on a paper and we didn't do any fun experiments.”

At the conclusion of the treatment period student’s combined positive and most positive attitudes toward science increased from 52% to 63%, an 11% increase (figure 3). In student interviews, all nine students said they liked science better this year. In

particular, one student said science is, “more fun, more outgoing stuff in it. He would just talk last year and you give examples.” Another student mentioned, “I like this year. We can work together.” A third student stated, “This year, I understand more than last year because it makes more sense.” As a teacher, I also noted my observations of the overall changes in students’ attitudes toward science class in my journal, writing “I sense that students have a better attitude toward science now than they did at the beginning of the year. I remember really being struck at the beginning of the year how dull these students seemed in science class. There just wasn’t as much curiosity and enthusiasm in this group as I have had in the years past. I feel like that has really turned around.” I believe this is partly due to the emphasis placed on understanding evidence and reasoning through the use of the C-E-R framework, so that students are not simply memorizing information they do not understand. This may be since the evidence and reasoning used higher level thinking skills that resulted in better understanding. On the other hand, much of students’ improvements in attitudes toward science may have also been due to my more interactive teaching style in comparison to the teacher they had the previous year.

Attitudes Toward Thinking and Learning

Students’ attitudes toward thinking and learning were also assessed. To begin, 62% of students had a combined positive or most positive attitudes toward thinking and learning in science class which increased by 5% to 67% at the end of the treatment (figure 3). To further understand students ideas regarding thinking and learning in science, three questions on the Likert survey were followed up with the open ended question, “Why did you answer that question in that way?”

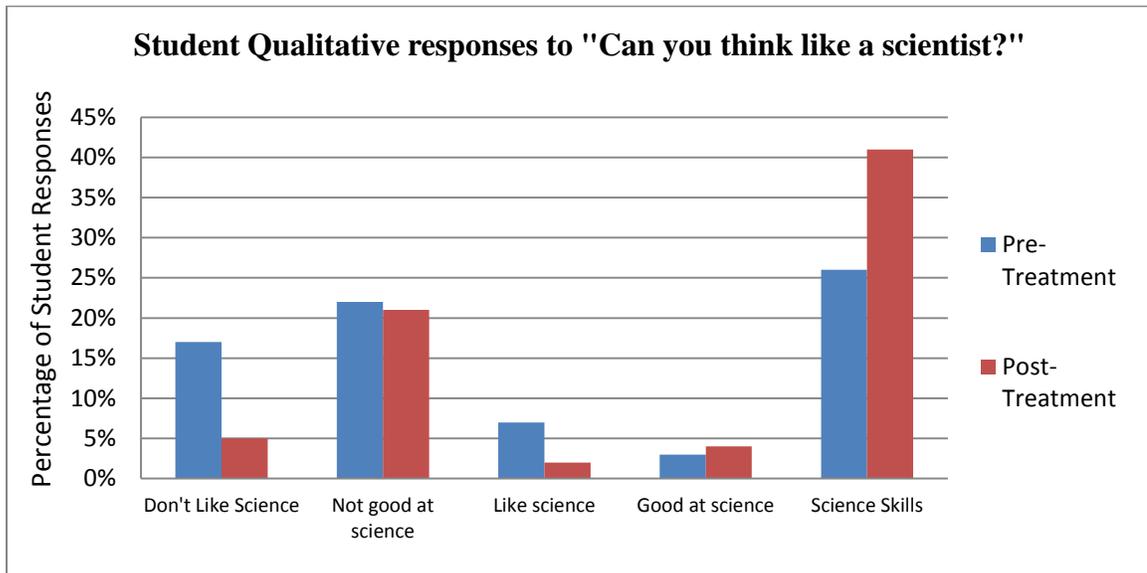


Figure 4. Responses to “I can think like a scientist,” ($N=115$ pre & $N=113$ post).

Follow up answers to the statement “I can think like a scientist,” generally fell within the following themes found in Figure 4 above. Most significant changes from this data revealed that the number of students who stated they do not like science as their reason for not thinking like a scientist declined after the treatment by 12%. For example, one student wrote, “I personal (sic) don’t think I can think like a scientist because I don’t like science.” In contrast, the percentage of students who cited their ability to use science skills as a reason for thinking like a scientist increased by 15%. For example, many of these students mentioned curiosity, questioning, observing, reasoning logically, or explaining things. For instance, “I’m just very curious and want to discover new things.” Another student shared “Because, I like to find out new things, and I think about things logically.” The data demonstrated an improvement in student attitudes toward thinking and learning in science, especially one quote in particular.

In response to why she can think like a scientist, one student wrote, “I’ve learned the C-E-R way of answering things which makes me think about evidence to back up my claim and then I give the scientific principle that also supports my claim. Scientists probably go through a process kind of like this in order to prove something.” To follow up on this quote, I shared this quote with all my students and asked them to what degree do they agree with it. Of the 105 students whose responses were collected, 21% strongly agreed, 69% agreed and only 10% disagreed or strongly disagreed. This data suggests that students understand that scientists also use evidence and reasoning to support claims and recognized that using the C-E-R framework helps them think like scientists.

Responses which were not represented in figure 4, did not fall within these main categories. Many of those gave arbitrary responses, others were outliers. For example, two students stated that they could think like a scientist because they believe in themselves and that they can do anything they set their mind to. One student mentioned she could not think like scientist because, in her words, “my religion taught me one way so I don’t question that.”

To further assess student attitudes toward thinking and learning in science, a Likert survey prompt, “Explaining scientific ideas helps me understand them better” was followed up with an open ended response. The percentage of students who strongly agree with this statement increased from 26% prior to the treatment to 36% after the treatment. A student who disagreed that explaining helps them learn stated, “For me to explain ideas gets me kind of stumped. If I were to try and explain something, I would be a little confused because when it comes to explaining; I know WHAT I want to say, just not HOW to say it.” This statement exemplified the need for the C-E-R writing framework

which provided the needed support to help students structure their written explanations. On the other hand, an example of typical statements for those who strongly agreed was, “I answered the way I did because it is said that if you can explain and teach what you learned you fully understand it. It also helps me understand scientific ideas better because I can hear other people’s ideas and add them to my thinking or explain why their thinking is wrong.” Following the treatment, many students specifically mentioned the use of the C-E-R framework, writing, “When I explain the reasoning behind scientific principals (sic) I can process the information better and writing CER's helps me understand the topics more.” Another student mentioned, “It helps me decide why the evidence is trustworthy and supports the claim.” In a similar statement, another student wrote, “When we explain experiments and other questions, the evidence and reasoning will help show how they work and why it is.” To conclude, following the treatment more students agree that forming scientific explanations aids in greater understanding of science content.

Attitudes Toward Writing

Overall opinions toward writing remained relatively the same prior to and after the treatment period. The Likert scale results from figure 3 showed that combined positive and most positive opinions toward writing improved by 2%. One writing survey question, “Writing helps me to understand science better,” was followed up with open ended responses, summarized in Figure 5 below. The most significant changes included an 8% increase in the number of students whose statement fell into the category that writing helps them learn, remember, and understand science. Responses included, “I learn the best when I write words down on the paper, as it strongly helps me remember and it improves my knowledge of thinking!” Another stated, “Well writing in science

class just helps the information to be glued into my head. It also helps me understand the subject more if I don't really understand it.” A third student remarked, “I can look back on my thoughts and reflect on them.”

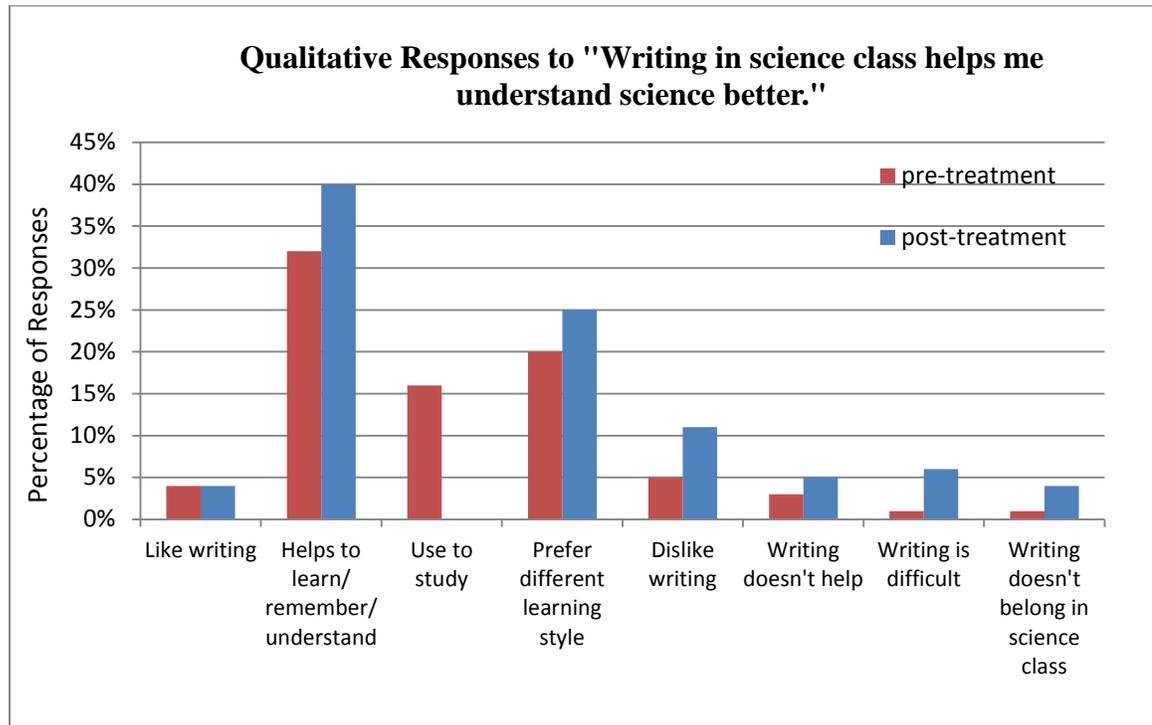


Figure 5. Responses to, “Writing helps me to understand science better,” (Pre $N=115$, Post $N=113$).

Prior to the treatment, 16% of students mentioned that they used notes in class to go back and study while no students mentioned studying notes as a reason for writing helping them understand science better (figure 5). I believe this is due to their prior experiences in science in which the main form of writing in science was taking notes. This was confirmed during student interviews as a student mentioned, “Last year we had to do Cornell notes for everything!” Another also mentioned, “last year the notebooks were too structured, we weren’t given any leash.”

In all, the remaining categories, “prefer other learning styles,” “dislike writing”, “writing doesn’t help,” “writing is difficult” and “writing doesn’t belong in science class,” all increased slightly after the treatment. Five percent more students cited that they preferred other learning styles as a reason that writing doesn’t help them learn science (figure 5). Typical thoughts included, “I don't usually learn well when writing things out. I am a visual person, I like seeing pictures and diagrams, graphs or experiments done so I can see it happen with my own eyes.” An additional insight was, “I like to do more hands on activities.” There was a 6% increase in statements like, “I don't like writing so it isn't very helpful.” It seems that writing scientific explanations using the C-E-R framework does not help improve students’ attitudes toward writing.

Student interviews may help understand why there was both an increase in opinions that writing helps them learn science while at the same time there were increase in statements about not liking writing and preferring to do other things in science class. One student in particular, Annette, typifies this contradiction. When asked in an interview how comfortable she felt making claims and supporting them with evidence and reasoning so far, she responded, “I don't like it, it takes too much time and it is a lot of work.” While she stated that she doesn’t like to write, when later asked if writing scientific explanations helps her learn science better she stated, “Yes, it stands out more [because] it’s a little repeat of what we've learned.” When then asked if using the C-E-R framework causes her to think more about what she is learning she answered, “yes, it takes a lot of thinking.” When asked if she learned content better using C-E-R than other learning methods she says, “No, pretty much the same. You are just putting down on paper what you already know.” Annette’s interview reveals that students who do not like

writing to begin with are not going to change their opinion by writing scientific explanations. Even if writing helps them to learn, they don't like to write because it forces them to think, which means they are working harder so they prefer to do other activities.

Application to Different Types of Lessons

One of the goals of my action research on writing scientific explanations was to try using the claims, evidence, reasoning framework with a variety of lesson types. Figure 6 shows the scores of 18 students from six different lessons in which the framework was used during instruction. The initial lesson on moon phases occurred prior to the introduction of the framework. This lesson was a lab using physical models to simulate the causes of moon phases. Following the modeling activity, students were asked to write an explanation, using evidence from the lab, to answer "What causes moon phases?" Data from the graph shows that the six high performing students on average scored 7.3 on their scientific explanations of moon phases out of the 9 point possible rubric. This demonstrates that these high performing students already know for the most part how to write an evidence-based explanation that accurately answers the causes of moon phases even before receiving instruction on the components; claim, evidence and reasoning. However, low to average performing students started out much lower with 3.8 and 4.2 averages showing these students did not know all the components in writing a scientific explanation.

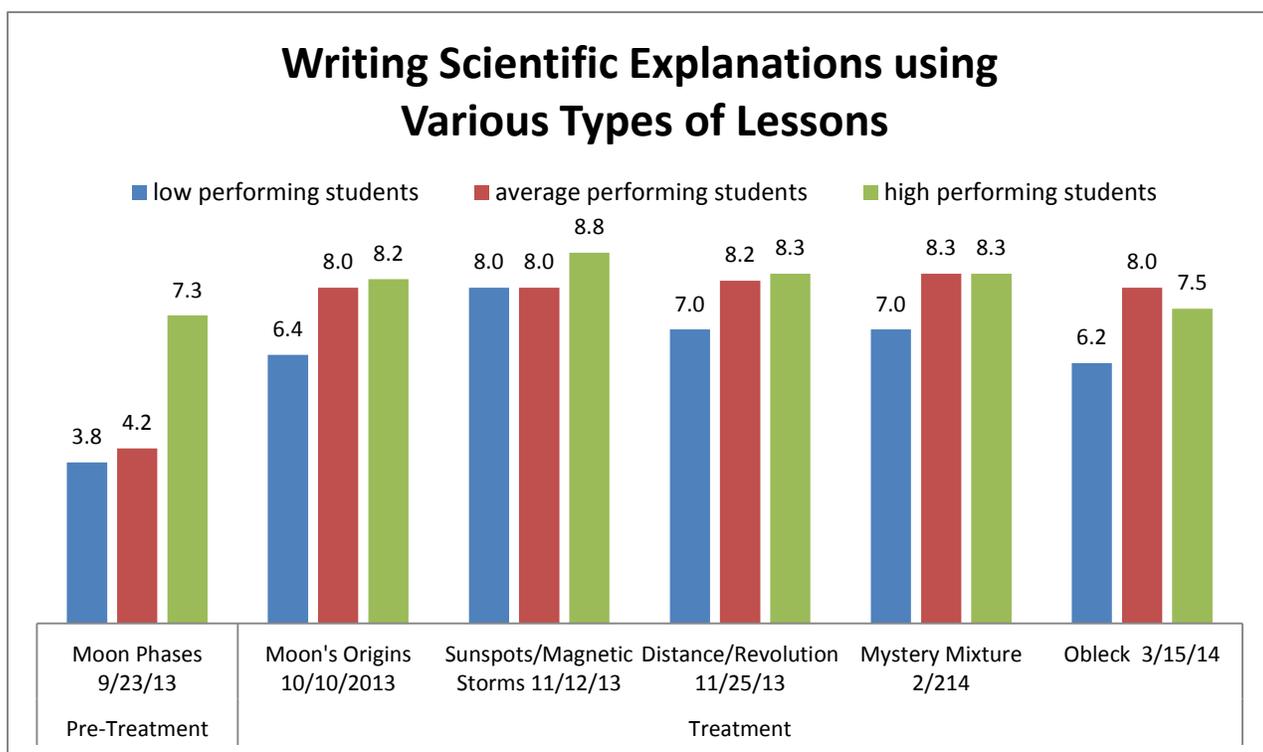


Figure 6. Applying Scientific Explanations to Different Types of Lessons, ($N = 18$).

The remaining lessons all occurred after the framework was taught to students and served as a means to evaluate the changes in the rubric score of students' explanations using different types of lessons. In the moon's origin lesson on October 10, students were provided 14 lines of evidence with reasoning regarding the origin of the moon. Students used this textual evidence to evaluate one of four theories of the moon's origin. I noted in my journal that "My 5th module period, there were more students that struggled with what the evidence means and were, therefore, not appropriately checking off if evidence supports, refutes, or is uncertain. Other classes seemed to have a much easier time of this. This 5th module class seems to have lower performing students." Some of the textual evidence and reasoning was challenging for many low performing students. The greatest

challenge for these students was in choosing appropriate evidence for their claim regarding the theory of the moon's origin. Even given that difficulty, low performing students explanations improved to a mean of 6.4. Average performing students made the greatest gains from pretreatment scores rising to a mean of 8.0, nearly as high as high performing students with a score of 8.2.

For the next C-E-R lesson on the relationship between sunspots and magnetic storms, students used textbook provided data from two graphs. This proved an easier task for low to average students who both scored 8.0 on average. This quantitative evidence was less complex than the textual evidence from the moon's origin. Students looked for correlations between the high and low peaks of graphs on both the number of annual sunspots and magnetic storms on earth. While these low to average performing students accurately and sufficiently included the claim and evidence, they still struggled to incorporate sufficient scientific principles in their reasoning. The high performing students not only included accurate and complete claims with appropriate and sufficient evidence but they were also able to include sufficient scientific principles using textual evidence from the text book resulting in an 8.8 average score.

Regarding this C-E-R lesson on sunspots and magnetic storm, I noted in my journal that "This was a different type of evidence from the moon's origin. This lent itself to writing a different structure. As students were writing, some students asked if they should [explain] their reasoning after each evidence as we did for the moon's origin. I hadn't thought about this structural difference until students asked about this. I therefore did an impromptu lesson on how the structure didn't need to be C-E-R-E-R-E-R, [meaning a claim followed by three sets of evidence and reasoning] since we are using

the same type of evidence but are using three different years from the graphs to show the pattern. Therefore, only one [explanation of the] reasoning was necessary, such as C-E-E-E-R [meaning the claim followed by three evidences and one reasoning for all].”

The third C-E-R lesson followed a lab in which students used a physical model with string and washers to simulate how a planet’s distance from the sun affects its period of revolution. Similar to the previous C-E-R lesson, students were using quantitative data but this time they collected their own data from the lab. High performing and average performing students’ mean scores were 8.3 and 8.2 respectively while low performing students’ score 7.0 on average. Again, low performing students had the most difficulty with including sufficient scientific principles in the reasoning component of their explanations. This time students needed to use knowledge of the scientific principle learned in a prior unit (that gravity decreased with distance) to explain why a planet’s period of revolution increases with distance from the sun.

The fourth lesson, Mystery Mixtures, applied the C-E-R framework to the first unit in chemistry. The data collected was qualitative descriptions of the physical properties of ten white components as well as descriptions of the bubbling or fizzing of various combinations of two components after adding water. Again, low performing students scored 7.0 on average while both average and high students scored 8.3.

The final C-E-R written following the Oobleck lab served as a means to assess students’ retention of the framework without previous use or reference to the framework for the month prior. Scores declined somewhat to 6.2, 8.0, and 7.5 for low, average and high performing students respectively. In my journal I noted that my expectations may have been too high for even most of my high students. “I challenged my students to...

apply their knowledge of the arrangement and motion of the particles in liquids and solids to explain the strange behavior of Oobleck. While many students could accurately use the scientific principles of the defining characteristics of solids and liquids, they fell short of explaining how applying pressure to Oobleck caused the particles in the Oobleck to momentarily hold their positions like a solid and therefore resist flowing.”

In summary, the C-E-R framework was applicable to the different types of lessons including textual evidence, qualitative and quantitative data, as well as data provided for students or collected by students themselves. While some tasks were more difficult than others, the C-E-R framework became the means for students to analyze and conclude labs within my classroom.

Effects on Content Knowledge

Following the completion of the each chapter, I compared the scores on questions relating to content taught using C-E-R to those questions relating to content taught without using the C-E-R framework. During astronomy units one and two, the C-E-R framework was used several times. During astronomy unit 3, content was taught without using the C-E-R framework. This allowed me to assess how well students would still be able to apply the framework on the essay test after not using it and see if there was any significant change in the closed answer questions scores as well. Chemistry Unit 1 applied the C-E-R framework following one chemistry lab while other content was taught without the framework.

The first astronomy unit focused on the effects of the relative positions of the earth, moon and sun. The second astronomy unit focused on the solar system. Topics included; characteristics of the planets, smaller bodies of the solar system, and the search

for life beyond Earth. Astronomy unit three included the topics; stars, galaxies, and the expanding universe. The first chemistry unit on chemical and physical properties of matter included; types of matter, density, and exothermic and endothermic changes in matter.

Following each of these units, tests included 20-31 closed ended questions given on the computers using Google forms. This portion of the test included multiple choice questions and fill in the blank questions using provided word banks. The second part of each test was a pencil and paper test which included four essay questions a paragraph in length each. After scoring the tests from each unit, I grouped the questions for the purpose of analyzing any difference in the scores for the content in which students used the C-E-R framework to those content questions in which the C-E-R was not used as part of the treatment.

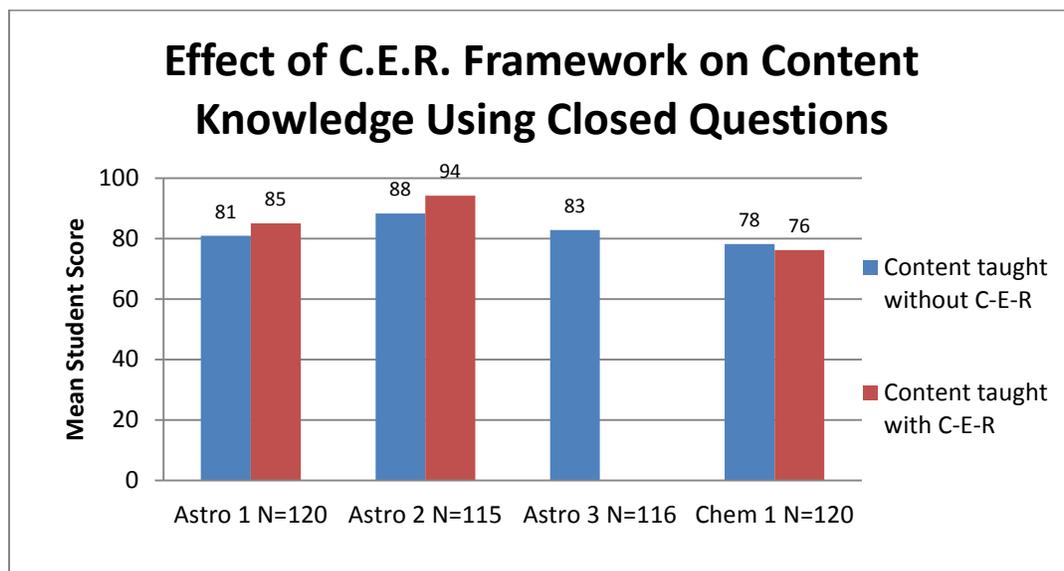


Figure 7. Effect of C-E-R on content knowledge Closed-Ended Questions.

The effects of the C-E-R framework on content knowledge using closed ended questions are shown in figure 7. The results are mixed with higher scores in content taught with C-E-R in astronomy units one and two while Chemistry Unit 1 showed a slight decrease in content knowledge on content taught using C-E-R framework. In Astronomy Unit 1, the mean percentage of correct answers on C-E-R taught content was 85% compared to 81% mean percentage of correct answers on content taught without C-E-R. This resulted in a 4% improvement in content knowledge with use of the framework. Similarly, Astronomy Unit 2 also resulting in a higher score for C-E-R taught content at 93% mean score compared to 88% mean for non-C-E-R content, a 5% difference. However, the chemistry unit ended with a 2% decrease in content taught using the framework at 76% mean compared to 78% mean on content taught without the framework. This decrease in the chemistry unit may be due to the degree to which the C-E-R lesson, Mystery Mixture, aligned with the test questions on this topic.

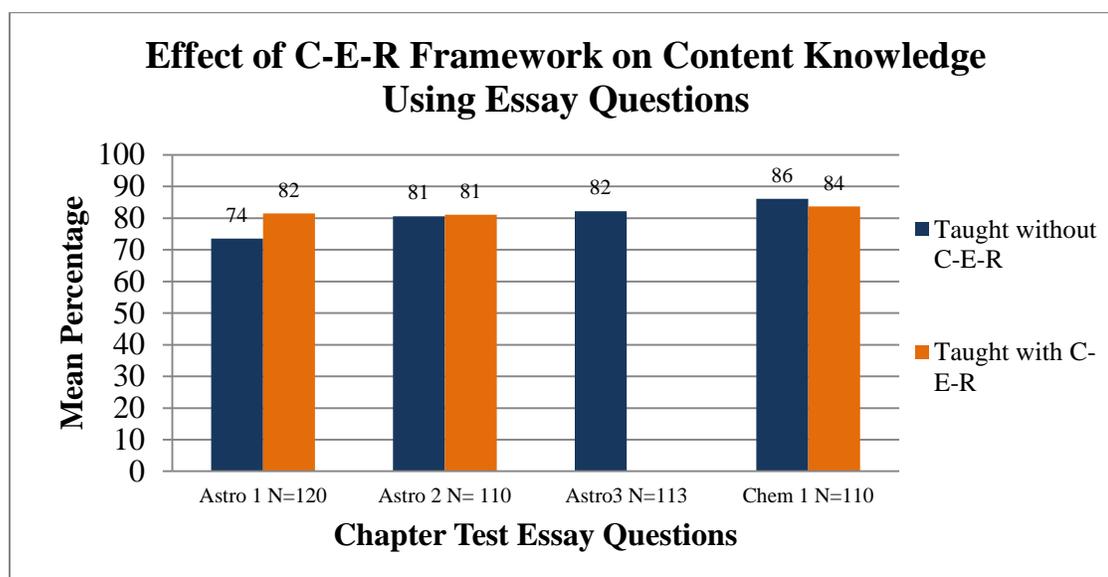


Figure 8. Effect of C-E-R on Content Knowledge Using Essay Questions.

Similarly, results were mixed using essay questions as shown in the graph in figure 8. The first astronomy unit resulted in an 8% higher mean of 84% on C-E-R taught content compared to 74% mean on other content. To test the validity of these first results on the effect of the C-E-R framework on student's content knowledge, I reported this result to my students and asked their opinion as to why the scores were slightly higher for that question. Of the 93 responses collected, 45% attributed the use of the C-E-R as helping them learn that information better, 30% stated other reasons and 15% were uncertain. Other possible factors mentioned by students for the slightly higher score were that the content was taught closer to the date of the test, it was more interesting, or that we spent more time on that than the other content.

The following two units in which content knowledge was compared did not result in higher scores on essay questions by using the C-E-R as part of instruction. Astronomy Unit 2 resulting in the same mean percentages at 81% for all content questions and Chemistry Unit 1 showed students actually scored on average 2% lower on questions which were taught using C-E-R. Mixed results may be due to how closely the C-E-R lesson aligned with the questions as presented on both parts of the test. For example, in the chemistry unit the C-E-R writing occurred following a "mystery mixtures" lab. In this lab, students observed the properties of ten white compounds when mixed two at a time and compared their reactions to that of the mystery mixture when adding water. Following the lab, students had to identify the two substances of the mystery mixture. The concepts imbedded in this lab were the physical and chemical properties of matter. Therefore, questions from the test which I grouped as content taught using the C-E-R related to identifying the differences between physical and chemical properties. In

retrospect, I did not emphasize the difference between the physical versus chemical observations enough while conducting the lab. Therefore, mixed results may be due in part to the alignment of C-E-R lessons with assessments.

In the previously described units of Astronomy 1, 2 and Chemistry 1, I compared students' scores on content taught using CER with content taught without using CER during instructional time. In one unit, Astronomy 3, the framework was not used at all during instructional time. At the end of the unit, students took an assessment which included four essay questions. Teaching a unit without using the framework served as a means to assess the retention of the framework by students.

When creating the questions for this non-treatment unit I noted in my journal how using the C-E-R framework was changing me as a teacher. "I have noticed a shift in my thinking as a teacher. I am much more thoughtful about the kind of essay questions I am asking. I find that I am asking myself, 'Does this question require students to provide evidence and reasoning, or is it simply asking students to recite memorized information? Am I asking questions that provide data, and ask students to use that data to get an answer or am I simply asking for definitions?'" After grading students' tests, I noted in my journal, "By using the C-E-R framework, I have to structure questions that allow students to use evidence, either presented with the question or knowledge from prior learning, and then apply that. For example, instead of simply asking students to explain how parallax is used to measure distances to stars, I present them with an image of stars taken in March and October. They then were asked, "Which star has the greatest parallax shift?" Students then have to apply their knowledge of parallax to give an answer. They then describe what they used as evidence to determine it, and applied the scientific

principle that the greater the parallax, the closer a star is to earth. I find that I am really spending more time structuring my questions more carefully. In the past, I think my questions were asking students to simply memorize the definitions. Now that I am asking them to apply the knowledge and explain their reasoning, I get more answers that are in their own words.”

The results of the non-treatment astronomy chapter are shown in figure 9. The graph shows that even though subjects were not taught using C-E-R, by structuring test questions to align with the framework resulted in higher average scores than the question not aligned to elicit a response structured in C-E-R. The topics of parallax, spectrums, and the big bang required students to include a claim, evidence and reasoning and resulted in average scores of 84%, 89% and 81% respectively. In contrast, the question on the lives of stars, not structured for C-E-R resulted in a lower mean score of 74%. The difference was notable in that students spent more time on the topic of lives of stars by creating collaborative, illustrated diagrams of the life stages of stars in class using an online program called Lucid Chart. These results showed the importance of structuring questions for C-E-R. Additionally, the data suggests when prompted to use the framework, students retained their skills after a month without practicing it.

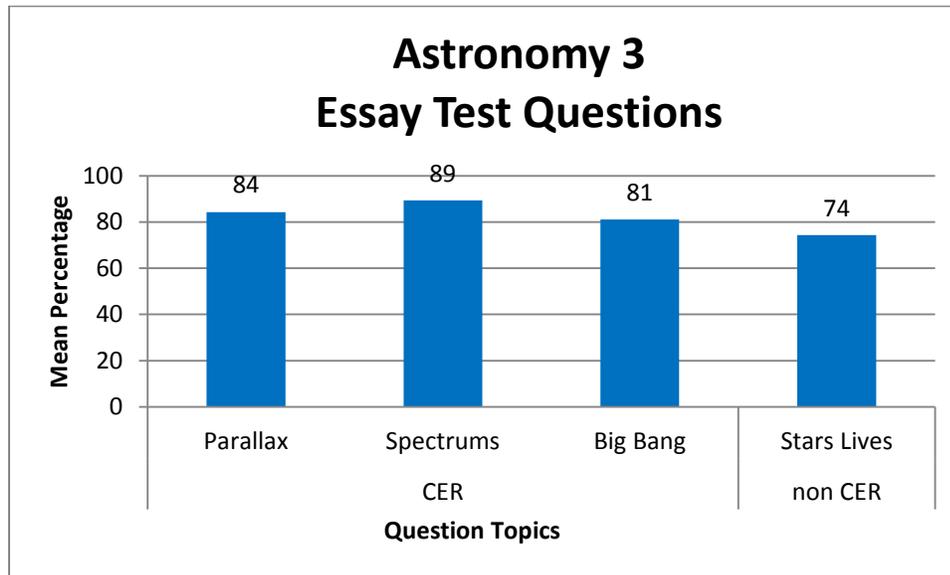


Figure 9. Comparing student scores on test questions structured for C-E-R verses questions not structured for C-E-R, ($N= 113$).

To restate, the data on the impact of the C-E-R framework on students' content knowledge yielded mixed results. As assessed on closed answer questions, students' scored slightly higher on content taught using C-E-R for two astronomy units but slightly lower for the chemistry unit (figure 8). The alignment of the C-E-R writing to the closed answer test questions may account for this discrepancy. Lastly, assessing student written answers from a unit in which C-E-R was not used during instruction showed that students retained their skills using the framework.

INTERPRETATION AND CONCLUSION

This action research sought to answer the main question of what effects the Claims-Evidence-Reasoning writing framework had on teaching and learning in an 8th grade science class. More specifically, through this action research, I wanted to determine if the C-E-R framework was applicable to a variety of lesson types. Additionally, this study looked at the impact the C-E-R framework had on student learning of science content.

This research also gathered data to determine the effect of the C-E-R framework on student attitudes toward writing, thinking and learning, and the nature of science. Lastly, the effects on me as a teacher were evaluated.

The first sub question of this action research was, “How does the C-E-R framework apply to different types of lessons?” This study presents data that the claims, evidence, and reasoning framework provided my students with needed support in writing evidence based explanations in a variety of lesson types. In particular, the scientific explanations of low to average performing students benefited the most from use of the C-E-R framework. Figure 6 shows that after instruction of the framework, low performing student scores increased (from 3.8 to as much as 8.3) and average performing students’ scores increased (from 4.2 to as much as 8.3). It seems that higher performing students may have intuitively already known how to write scientific explanations that included most of the needed components so this subgroup showed the least impact from instruction in the framework (increased from 7.3 to as much as 8.8).

The next sub question of this action research was, “How does the C-E-R framework affect student attitudes toward writing, thinking and learning, and the nature of science?” Students’ reported many benefits to using the C-E-R. Students indicated that using the framework caused them to think more about the science content (nine out of nine in student interviews). On the post Likert survey, students mentioned that having to explain reasoning helps them “process the information better” and helps them to “understand the topics more.” Additionally, students believed the framework helped them to “decide why the evidence is trustworthy and supports the claim.” In a similar statement, another

student wrote, “When we explain experiments and other questions, the evidence and reasoning will help show how they work and why it is.”

Results from this study show that using the C-E-R framework increased my students understanding of the nature of science. Following the treatment, figure 4 shows more students cited their ability to use science skills as a reason for thinking like a scientist (increased by 15%). Student improvement in understanding of the nature of science was exemplified with this student quote, “I’ve learned the C-E-R way of answering things which makes me think about evidence to back up my claim and then I give the scientific principle that also supports my claim. Scientists probably go through a process kind of like this in order to prove something.” Additionally, the Likert survey resulted in more positive attitudes toward the nature of science (increased by 6%).

Continuing, the action research gathered information to try to answer the sub question, “How does the C-E-R framework impact students’ content knowledge?” From this study, it is unclear whether using the claims, evidence, reasoning framework improves students’ content knowledge. Comparing scores on test questions on topics in which the C-E-R framework was used during instruction to content taught without writing C-E-R did not show significant affects. This may have partly due to how well the test questions aligned with the lessons in which students wrote scientific explanations using the framework. During the course of the treatment, I became better at tailoring questions to require analysis of evidence rather than simply asking for definitions or memorized content. Figure 9 shows that structuring test questions in a way that required C-E-R answers of students resulted in higher scores than when not structured for C-E-R (nearly 11%).

Although test score results were mixed, students reported in student interviews that using C-E-R helped them learn science content (8 out of 9) and most also said it helped them learn content better than other learning methods (7 out of 9). To exemplify this, one student stated, “I don't have to spend so much time studying for tests because I understand the material more. I had to memorize the steps last year but now I don't have to memorize as much because I understand it better.” Further study with carefully aligned lessons and test questions is necessary to form conclusions regarding the affect the framework has on students' content knowledge.

To restate, the major results from this study show that the C-E-R framework is useful with a variety of lesson types in an 8th grade science class. Students found the framework helped them learn science content and helped them to structure their writing when asked to write an evidence based explanation. Using C-E-R also improved students understanding of the nature of science.

I will continue to use the C-E-R framework in the future since it improves students' understanding of the nature of science, helps students in learning science content, and provides necessary scaffolding for students to write evidence based explanations. Using the framework helped me as the teacher to focus more on the evidence and reasoning behind content. Therefore, I felt I covered topics more deeply. I also found that using the framework helped me to ask higher level thinking of my students because I had to ask questions in a way that could be answered using evidence and reasoning instead of simple recall questions. For example, in the past, I may have simply asked students to calculate the density of a material. In contrast, to structure for a C-E-R answer, I asked the following question, “A 17-gram of an unknown material has a

volume equal to 20cm^3 . Which material from the list is it likely to be and will a solid piece of this material sink or float in liquid water?" This question required students to not only calculate the density, but to also explain the scientific principle they used to determine if it floats or sinks. In the future I will use the C-E-R framework as a way to conclude labs, discuss science news articles and a means to structure test questions to assess student understanding.

A difficulty I found implementing the C-E-R framework was providing feedback to students. Since students were generating a greater volume of writing, this posed a challenge in providing timely and specific teacher feedback to all students for all assignments. For most class assignments, I instead used peer review using the rubric, as it would be difficult for me to read every student assignment every time the framework was used. For all C-E-R used on tests, I provided specific feedback to all students, not simply a grade. While many students reported in student interviews they found the peer review very helpful, I noted that a higher performing student indicated the helpfulness of peer review depended on the student they were paired with. This could be alleviated by pairing students first in heterogeneous pairs so that lower performing student may benefit from feedback from higher performing students. Then, students could be paired homogeneously, so that high performing students may also benefit from feedback from other higher performing students. All students interviewed said that teacher feedback was very helpful. The effectiveness of peer feedback versus teacher feedback in improving evidence-based scientific explanations is a question of possible further action research.

Another difficulty I found was that implementing more writing into my curriculum through the C-E-R framework was more time consuming. I found it

challenging later in the year to make sure I covered all content still required as part of standardized state tests. To help streamline next year, I plan to still introduce the framework first with a non-science topic from popular culture. However, I think this would best be done as part of the first days of school as a means to get to know students as well as set the foundation for explanations in which students' claims are supported with evidence and reasoning. I also plan to selectively apply the C-E-R framework to only the big ideas of my curriculum to allow me to get through content in a time frame that better accommodates teaching to all the tested standards.

VALUE

The simplicity of the C-E-R framework and its effectiveness with a variety of lesson types means other science teachers can easily incorporate its use in any science class. Given the benefits to my students understanding of the nature of science, other science teachers could benefit from implementing the C-E-R writing framework within their classes. Understanding the nature of science is critical given that our society is based on science and technology. Students will be presented with news media that, in an effort to present balanced news, often report two sides for every scientific news story. Students will need the ability to evaluate scientific claims and the validity of supporting evidence to make sense of conflicting claims. If students are trained in the skills of writing and evaluating scientific explanations, this implies they may have the skills to become scientifically literate citizens. I often quote Carl Sagan to my students, "We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology. This is a clear prescription for disaster." Focusing science instruction on evaluating the evidence and reasoning behind claims

through use the C-E-R framework may be a small step toward the goal of producing scientifically literate students. Using the C-E-R framework may even have value beyond the academic world of students. Using the skills of evaluating evidence and thinking logically may help students as they navigate through a media rich world full of claims from pop culture, products, and politicians.

Although my use of the C-E-R framework focused on scientific explanations, I believe there may also be application for the framework within other subjects. While the specifics of what counts as appropriate evidence would vary within a history, mathematics, or language arts classrooms, the basic structure may be as effective in supporting claims within these disciplines as it is in science. Therefore, I would like to reach out to the greater community of LFCS teachers to share the C-E-R framework at staff trainings as a means to meet the requirements of argumentation as set forward through the language arts and mathematics common core standards.

To further my research into the effect of writing scientific explanations using the C-E-R framework, I would like to expand the framework to include the rebuttal. While my action research was limited to the first three parts of a scientific explanation, I believe the addition of the rebuttal may further impact students' understanding of content, evaluation of claims and argumentation skills. This would be a natural extension of this action research project.

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APPENDICES

APPENDIX A
TREATMENT SCHEDULE

Activity	Treatment	Unit Topic	Tentative Dates
Activity	Pre-Treatment & Treatment introduced	Effects of Relative Positions of Earth, Moon and Sun.	October 2013
Begin field observation journal			
Causes of Moon Phases Lab: Using observations from the Sun, Earth, and moon model, students will be asked to write an explanation of what causes moon phases. Teacher will not introduce the C-E-R framework at this time.			
Score and record select student explanations of causes of moon phases using the C-E-R rubric.			
Introduce C-E-R using non science examples first. Have students write C-E-R about a pop culture topic such as best musician, sports team, video game, etc...			
Use the C-E-R framework to evaluate four claims of the moon's formation. Students will make a claim as to whether their assigned claim is likely or unlikely given evidence of the moon. Score with rubric.			
Chapter 1 Test - Compare student scores on questions pertaining to non-treatment (moon phases, seasons & eclipses) and treatment (moon's origin). Questions will include multiple-choice, fill in and paragraph answers.			
Proposed Lessons	Treatment	Chapter Topic: The Solar System	November & December 2013
Using graphs of annual sunspots and magnetic storm days, students will be introduced to the C-E-R rubric before writing an explanation of the relationship between sunspots and magnetic storms on Earth.			
Using data collected from a lab, student will write an explanation using the C-E-R framework to answer the question, "How does a planet's distance from the sun affect its period of revolution?"			
Using a C-E-R framework, teacher will guide students to identify textual evidence within an internet source to support the claim that Mars may have once had the conditions needed for life to exist.			
Chapter 3 Test – Evaluate student scores on questions relating to topics taught using C-E-R (evidence for life on Mars, sun spots/ solar flares, and a planet's distance from the sun) to those topics taught without C-E-R.			
Student Interviews			
Proposed Lessons	Non-Treatment	Chapter Topic: Stars, Galaxies, and the Universe.	January 2014
Chapter 4 Test. Evaluate students' scores on questions regarding content.			
Lessons	Treatment	Chapter Topic: Properties of Matter	February 2014
Students will determine the substances contained within a mystery mixture by observing properties of known compounds. Then write an explanation using C-E-R.			
Chapter Test - Evaluate students' scores on questions regarding content knowledge of physical and chemical changes.			
Final Likert Survey			
Lessons	Non-Treatment Period	Chapter Topic: States of Matter	March 2014
Assess retention of CER framework. Students write explanation of "Oobleck."			

APPENDIX B
EXEMPTION FROM IRB



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
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MEMORANDUM

TO: Tanya Long and Walt Woolbaugh
FROM: Mark Quinn, Chair *Mark Quinn CJ*
DATE: December 9, 2013
RE: "The Effects of the Claims-Evidence-Reasoning Framework on Teaching and Learning in an 8th Grade Science Class" [TL120913-EX]

The above research, described in your submission of December 9, 2013, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

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

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

APPENDIX C

STUDENT SURVEY ON ATTITUDES TOWARD SCIENCE AND WRITING

Student Survey on Attitudes Toward Science and Writing

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

Your username (tanya.long@lfcslinc.org) will be recorded when you submit this form. Not [tanya.long?](#) [Sign out](#)

* Required

1. **Science is essentially an accumulation of facts to be memorized.** *

Mark only one oval.

1	2	3	4	
Strongly Agree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Disagree

2. **Science is essentially about explaining the world around us.** *

Mark only one oval.

1	2	3	4	
Strongly Agree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Disagree

3. **Science is actually based on the best available evidence at the time; it may change with new evidence.** *

Mark only one oval.

1	2	3	4	
Strongly Agree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Disagree

4. **Most scientific claims are educated guesses.** *

Mark only one oval.

1	2	3	4	
Strongly Agree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Disagree

5. **Trustworthy scientific claims are supported with evidence and reasoning.** *

Mark only one oval.

	1	2	3	4	
Strongly Agree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Disagree

6. **I am good at science.** *

Mark only one oval.

	1	2	3	4	
Strongly Agree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Disagree

7. **I enjoy learning science** *

Mark only one oval.

	1	2	3	4	
Strongly Agree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Disagree

8. **I can think like a scientist.** *

Mark only one oval.

	1	2	3	4	
Strongly Agree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Disagree

9. **Why did you answer the last question this way?** *

10. **Science helps me become a better critical thinker.** *

Mark only one oval.

	1	2	3	4	
Strongly Agree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Disagree

11. **Science is dull and boring.** *

Mark only one oval.

1 2 3 4

Strongly Agree Strongly Disagree

12. **Science is more interesting than most school subjects.** *

Mark only one oval.

1 2 3 4

Strongly Agree Strongly Disagree

13. **I like writing.** *

Mark only one oval.

1 2 3 4

Strongly Agree Strongly Disagree

14. **I am good at writing.** *

Mark only one oval.

1 2 3 4

Strongly Agree Strongly Disagree

15. **Writing in science class helps me to understand science better.** *

Mark only one oval.

1 2 3 4

Strongly Agree Strongly Disagree

16. **Why did you answer the last question this way?** *

17. **Explaining scientific ideas helps me understand them better.** *

Mark only one oval.

	1	2	3	4	
Strongly Agree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Disagree

18. **Why did you answer the last question this way?** *

APPENDIX D
STUDENT INTERVIEW QUESTIONS

STUDENT INTERVIEW QUESTIONS

1. How are you enjoying science class so far this year? What has been your favorite lesson so far this year
2. How is science class this year compared to how past science classes have been like?
3. How comfortable do you feel making claims and supporting them with evidence and reasoning so far?
4. When writing scientific explanations, which component is most difficult for you?
 - a. Why is this part difficult for you?
 - b. What might make this part easier for you?
5. When writing scientific explanations, which component is easiest for you?
 - a. Why do you think that is?
6. How useful is the C-E-R rubric in helping you write scientific explanations?
 - a. Does the rubric help you know what include or what kind of changes to make to improve?
 - b. Have you ever done anything like this before?
7. Does writing a scientific explanation help you learn the science content?
 - a. Does the C-E-R framework force you to think more about what you are learning in science?
 - b. Do you think you know the content that you have to write explanations for better than content you have not had to write explanations for?
 - c. Why do you think that is?
8. How helpful is teacher feedback in improving your scientific explanations?
 - a. What kind of feedback is best for you? Written, verbal, positive, or constructive?
9. How helpful is peer feedback in improving your scientific explanations?
10. Is there anything else you want to tell me about how your science year is going so far?

APPENDIX E
SURVEY #2

Survey #2

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

Your username (tanya.long@lfcisinc.org) will be recorded when you submit this form. Not **tanya.long**?

[Sign out](#)

* Required

1. On the chapter 1 test, student's did slightly better on question #4 (moon's formation) than they did on the other three questions (moon phases, seasons and gravity.) Why do you think that is so? Do you think it had anything to do with writing a C-E-R about the moon or do you think there were other reasons? *

2. How is science class this year different than last year? *

3. Many of you responded to the last survey that you think science is boring. Is this opinion based on your experience this year in science class OR on past experiences with other teachers? *
