

FORMING EXPLANATIONS FROM EVIDENCE USING
THE CLAIM-EVIDENCE-REASONING
FRAMEWORK

by

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ABSTRACT

While the students perform labs and get results, they do not take the time to carefully analyze the results and draw conclusions that relate the lab to the concepts that are being learned. The focus is on completing the lab itself and it is difficult to get them to draw connections to the concepts and use the scientific language in their conclusion writing.

This classroom research project investigated whether explicitly teaching a conclusion writing framework increased students' capability to draw conclusions from the lab work as well as increase their understandings of the concepts. The claim-evidence-reasoning framework was used to teach the students conclusion writing protocol and help analyze data. After the framework was introduced, the students practiced with it. Then it was integrated into daily activities, like labs and journal check-ins.

Data collection methods included lab reports, journals, conclusion practice, surveys, interviews, and a pre/post assessment. The data collection methods were aimed at determining if students' ability to analyze data and provide appropriate scientific reasoning improved, along with gauging their attitudes towards learning and understanding of the scientific concepts.

There was no strong connection found between the use of the framework and students' ability to understand the concepts. The use of the framework did improve students' ability to make a claim and use evidence within conclusion writing, but the students' still struggled with the reasoning section. There was a shift towards students feeling more capable of using evidence and reasoning in their conclusion writing, but this did not translate to student confidence in conclusion writing.

INTRODUCTION AND BACKGROUND

Poultney High School was in Poultney, Vermont, a small, rural community with a population of about 1,600 in 2013. At the time of this study, the town was home to Green Mountain College, a small private school. The average family income in Poultney was \$40,723 and the median age is 23.6 years old. The town was 93% Caucasian, 2.2% Hispanic, 2% black, 1.1% Asian, and a small fraction of others (Poultney, Vermont, 2016).

The high school served grades seven through twelve with approximately 210 students from Poultney, Middletown Springs, and Wells along with a few students who have used school choice to come to Poultney from Fair Haven. The school motto was “Small in size, big in spirit”. The town held strongly to its sports, particularly football, and traditions, which were still a great source of pride for the town. Class sizes were generally small, about 15 to 18 students, and there was a wide range of abilities and motivation within the students. Classes were 73 minutes long and met everyday for a semester (mid-January to mid-June).

In my classroom I found that students struggled with making connections between evidence and the conclusions they were drawing. In particular, they did not seem able to explain why the evidence supported their conclusions. Though students seem engaged through the activities and labs, there was often a struggle to connect what was learned to new concepts and sometimes even to make a connection to the material we were working with. The students did not take the initiative to move their learning forward and make these connections, but they were often compliant and did the minimum amount of work.

Hopefully, by explicitly teaching students to analyze data and evidence, their ability to self-explain how they were solving their problems or creating their explanations would improve. As students' ability to understand how they were solving problems increased, their base knowledge should improve. This should impact their ability to understand concepts and to apply new ideas to relevant situations.

To explicitly teach students to analyze data and to promote students' ability to write explanations, the claim-explanation-reasoning (CER) framework within an inquiry setting was implemented. This could have benefited the students because it tied directly to the science and engineering practices in the Next Generation Science Standards. The students worked on practice 6 (constructing explanations), practice 7 (engaging in argument from evidence), and practice 4 (analyzing and interpreting data). Supporting explanations with evidence and learning to use evidence to draw conclusions were skills that students should have been using in their everyday lives, not just for science purposes. Analyzing data before drawing conclusions could have led the students to be more informed citizens. The inquiry setting was implemented to promote engagement with the material and was undertaken in an effort to prompt students to take more responsibility for their own learning. The CER framework was implemented so that students can have a scaffolded approach to analyzing data.

My primary research question was "How will students' ability to use evidence to form explanations impact their content mastery?" The following sub-questions were also addressed: 1) If students practice using an outline based on CER in their scientific writing, will it improve their use of evidence in conclusions? 2) In what ways does

implementing a conclusion writing framework and practice analyzing data improve students' ownership of the learning process?

CONCEPTUAL FRAMEWORK

A review of the literature on using inquiry in the science classroom, specifically the claims-evidence-reasoning (CER) framework, to promote formulating explanations from evidence was broken into three discussion topics. The first grouping looked at literature that focused on the benefits of inquiry in the classroom. The next grouping focused on the importance of writing explanations and argumentation in writing. The last grouping focused on strategies (including CER) to promote formulating explanations in an inquiry-based classroom.

Duschl (2003) stated that “science at its core is fundamentally about acquiring data and then transforming that data first into evidence and then into explanations” (p. 47). To this end, he referenced what the National Research Council recommended as five major features that should be incorporated into classroom inquiry. These features included: 1) Learners are engaged by scientifically oriented questions 2) Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions. 3) Learners formulate explanations from evidence to address scientifically oriented questions. 4) Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding. and 5) Learners communicate and justify their proposed explanations.

Forming explanations from evidence was one portion of inquiry-based learning. Inquiry based learning, if implemented efficiently, could help challenge misconceptions

and encourage students to use background information. Students who learned through the inquiry method saw larger gains in understanding the concepts, though they may not necessarily have been more confident about their learning ability (McCright, 2012). One research project determined that students who were taught in an inquiry fashion, using the 5E learning cycle model, made significant gains over students who were taught by the same teacher in a traditional manner (Abdi, 2014). The gains were particularly prominent when questions were open to interpretation.

Inquiry could promote thinking like a scientist since there were not necessarily deterministic outcomes in the experiments being conducted and students had to be able to examine the data to draw a valid conclusion. While inquiry based projects were a great basis to allow students to practice forming explanations from evidence, greater success was found when skills like examining data were taught directly within the inquiry format. Without direct instruction, students had difficulty explaining their thought processes and could not come up with a consistent way to solve problems (Lee, Anderson, Betts, & Anderson, 2011).

Forming explanations in the science classroom was the ability to use observations and/or previous knowledge to not only draw a conclusion, but also support that conclusion with evidence (McNeill & Krajcik, 2012). Constructing explanations and designing solutions was one of the science and engineering practices (NGSS, 2013). Constructing explanations in science used claims to respond to questions being asked through the scientific process. This practice was defined in the Framework as “Asking students to demonstrate their own understanding of the implications of a scientific idea

by developing their own explanations of phenomena, whether based on observations they have made or models they have developed, engages them in an essential part of the process by which conceptual change can occur” (NGSS, 2013).

This was a difficult task for students to accomplish and required both knowledge of the concepts and the ability to think critically about these concepts. While this may have seemed evident, it had been shown that students who could think critically about concepts could make more content gains. This was because the ability to think critically allowed students to make more correct connections while they were processing and organizing new information. This whole learning process was intertwined, and students who had better reasoning skills ended up making more concept gains as a result (Moore, 2012).

Students’ ability to self-explain, or explain to themselves how and why they solved a problem the way that they did, was found to be linked to their ability to determine the right answer. In addition, it was determined that students had to access their background knowledge in order to make full use of the benefit of being able to self-explain (Jonas, Cernusca, & Collier, 2012). If students practiced forming explanations, they should not have been able only to build up their prior knowledge but also to increase the gains they would have made in the future with the added skill of analyzing and assimilating data.

While curiosity of students was natural and discussed as something to be tapped into to engage students in learning science, students may not have naturally practiced their critical thinking skills. Analyzing data and using appropriate evidence to support an

explanation could have been a daunting task to a student. While some students may have been exposed to this, the majority of students needed to be taught these skills directly. Studies have shown that overtly teaching these skills was required in order for students to maximize the benefit (Ruiz-Primo, Li, Tsai, & Schneider, 2008). While the processes could have been included within teaching, if they were not explicitly pointed out and practiced, students still saw few gains. Ruiz-Primo, et al. (2008) stated the following:

The magnitudes of the correlations indicate that engaging students in the construction of high quality explanations might be related to higher levels of student performance. We interpreted this finding as evidence that engaging students in the construction of explanations can lead to expected positive impact on their understanding. The opportunities to construct these explanations, however, seem to be limited (p. 36).

Some thought should also be given to evaluating the formation of explanations. There was evidence that keeping an ongoing record of students' achievement throughout the inquiry process and frequent check-ins provided much more reliable and in depth information than if only the final product was evaluated (Harrison, 2014). In this context, while valuable information could have been gained from evaluating the student's pre-test and post-test explanations, there should also have been a method to collect data while students were actively forming these explanations. Especially since evaluating evidence was an ongoing process and students may have been making adjustments throughout an inquiry experiment, a method of tracking these "internal" explanations would have been useful.

By providing students with the CER framework within an inquiry investigation and explicitly reviewing this process, the students should have gained the capability of

explaining their thought processes while writing explanations from evidence. The framework should have provided a strong outline and scaffolding technique to provide the student with a malleable baseline to expand upon. McNeill and Krajcik (2012) stated “By making the implicit rules of science explicit, the framework helps students see how to justify claims in science.” (p. 21). The framework could have given students a better idea of what a scientific explanation was supposed to look like and what should have been included.

Quick tasks and journal reflections could have been used to promote practicing incorporating evidence into explanations. It was noted in one study that students who had greater success at making observations, generally saw more gains when it came to using evidence to support their conclusions (Park Rogers, 2009). Practicing observations prior to implementing an inquiry project or introducing the CER framework may, therefore, have been beneficial to the students.

The most difficult portion of implementing the framework would have occurred during the reasoning portion. Students might have easily associated a claim and evidence, but not really have been able to connect the dots as to why they believed that the evidence they chose fully supported their claim. This was where explicitly teaching the critical thinking and reasoning skills came into play. Again, direct teaching around topics like critical thinking allowed for greater achievements by the students within projects like an inquiry-based investigation (Friedel et al., 2008). Another study provided evidence that explicitly teaching what a scientific explanation was and setting a clear classroom norm for what a scientific explanation should look like also greatly

improved the students' ability to construct a scientific explanation (Saglam, Karaaslan, & Ayas, 2014).

Suggested strategies to directly teach connecting evidence to reasoning included practicing making observations and collecting data, identifying whether they were making direct or indirect observations, practice tasks that allowed the students to sort through good and bad data, and journal reflections that allowed the student to focus on an explicit question related to forming explanations (Park Rogers, 2009). The CER framework broke up the parts of the conclusion or explanation so that the students had to identify and reflect on the pieces separately. By supplying and practicing with the CER framework students would have had a basis of what should have been included in a well written explanation. These strategies all could have been used to improve students' formulation of their explanations.

Evaluating and assimilating valid evidence to form a meaningful explanation that addressed the question being asked could demonstrate that a student had mastered material. Being able to draw their own conclusions from observations they had made and support them with correctly used evidence demonstrated that the students had processed the information. The inquiry-based classroom encouraged students to form explanations that were supported by evidence. Within the inquiry-based classroom, the CER would have provided a framework of direct instruction that should have maximized the benefit the students saw from practicing writing explanations from evidence.

METHODOLOGY

My classroom research project looked at whether using the Claims Evidence and

Reasoning (CER) framework to promote students' written explanations from evidence had a positive impact on their understanding of the concepts. My research sub-questions were: 1) If students practice using an outline based on CER in their scientific writing, will it improve their use of evidence in conclusions? 2) In what ways does implementing a conclusion writing framework and practice analyzing data improve students' ownership of the learning process?

Participants

The intervention was implemented during a six-week period in my spring 2017 earth science class, which was comprised of fifteen ninth graders (seven females and eight males). This course was the first science credit requirement for high school and met for seventy-three minutes every day for a semester (mid-January to mid-June).

The research methodology for this classroom research project received an exemption by Montana State University's Institutional Review Board, and compliance for working with human participants was maintained. Parents and students received a consent form (Appendix A) prior to implementing the intervention.

Intervention

For the classroom research project group in the spring, students' evidence-based conclusions were measured while implementing the CER framework as an instructional strategy within two units in the first half of the earth science class. The focus of using the CER within labs, journals, and data analysis was to allow students to reflect on the big ideas of the units.

To start the intervention and set a baseline, students took the online student survey

(Appendix B) and a pre-test (Appendix C). The CER framework was explicitly introduced through a presentation. Students were then given one invention and were asked to come up with evidence and reasoning for why it may be considered the top innovation during the time it was invented. Their arguments were summarized and discussed as a class in an effort to demonstrate a compelling argument and set an example. Students practiced in groups by ranking the ten best inventions based on the magnitude of impact of each the year they were introduced. The students also practiced the framework with an individual murder mystery assignment and reviewed each other's work using a rubric and peer review sheets (Appendix D). Finally, they had the opportunity to re-work their conclusions. At this point, expectations were reviewed as a class, and an anchor chart was created for reference throughout the remainder of the units. After the intervention was introduced, the students continued practicing with the CER framework with a number of guided labs, assembled labs, and data analysis--all through a minerals and rocks unit and weathering unit.

Data Nuggets, real world data collected and set up for students to review and analyze, were used to practice using the CER framework as well as conclusion writing. The Data Nugget titled "Growing Energy: Comparing Biofuel Crop Biomass" (Data Nuggets, 2016) allowed students to practice with data that was a little messy while making real world connections. With this Data Nugget, students used the framework, peer reviewed the framework, and then wrote their conclusions based on the feedback from the peer reviews.

Within the first unit, minerals and rocks, CER was used after labs to write

conclusions and to tie concepts being taught to the Next Generation Science Standards. The CER framework was also used after each student prepared a presentation on phytomining to evaluate all of the presentations and determine which “researcher” deserved grant money for the proposal. Journal prompts were used at the end of class to check in with the students and ask them specific questions to gauge their understanding of the CER framework process and their progress of using evidence to form explanations. For example, after the idea of the rock cycle and sedimentary rocks had been introduced, students were asked to use the CER framework to support the claim that sedimentary rocks in Utah could have once been part of the Appalachian Mountains. This allowed students to reflect on the content and tie in previous material.

During the second unit, weathering, students were designing an inquiry project based on the Next Generation Science Standard HS-ESS2-5: Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. The students could design a project focusing on stream erosion, freezing and thawing, glaciation, melting points of materials, or acid rain. The students designed and performed their experiments and used the framework to write an explanation from their own data. Journal prompts were used to gauge students’ attitudes toward the CER framework during this time period. The post-test was administered at the end of the unit and allowed the students to analyze evidence and write an explanation and the online student survey was retaken.

Data Collection

Written conclusions within the pre-test and post-test, journals and explanations of

observations and data, Data Nugget analyses, and lab reports were graded with a rubric on a one to four scale (Appendix D) based on the work of Ruiz-Primo, et al. (2008), specifically looking at the quality of the components of an explanation. The rubric examined the quality of student explanations, specifically type of evidence provided, nature of evidence provided, and sufficiency of evidence. The rubric scores were compared to assessment scores in order to identify trends.

A series of journal entry questions (Appendix E) were used as formative assessments to determine their progress and comfort in using evidence in their explanations, as well as their ownership of the process. A rubric was used to grade the journals (Appendix F), which was based on a one to four scale for three main assessment criteria and was modified from Boston Public Schools Department of Science (2016). The three main assessment criteria were quality (or how students made sense of the lesson), organization and completeness. If the journal prompt included practicing conclusion writing or drawing conclusions using the CER framework, the prompt was also graded using the CER rubric.

A pre- and post-survey was implemented to evaluate students' comfort with the CER framework and their ownership of the learning process. The pre-survey was given to the students prior to the classroom project intervention and the post-survey was given to the students after they had completed the post-test and final inquiry project.

The focus of the student interviews revolved around gaining insight into what students thought of the intervention process and how they benefited from it. Questions were asked to learn how confident students were with the material that had been learned,

and specifically what methods had benefited or not benefited them as they learned the material. Students were also asked about their level of engagement in different activities. Interviewees were selected to obtain a cross section of the ability level in the class based on the results of their pre-test. Two students were chosen from each of the low, middle, and high ranges of the pre-test results. In addition, students that made significant noticeable gains or no noticeable gains were targeted within those groups for interviews to gain further understanding of what worked and did not work well for them. Interview questions are included in Appendix G. Table 1 summarizes the data sources collected during the intervention.

Table 1
Data Triangulation Matrix

Focus Question	Data Source 1	Data Source 2	Data Source 3
How will students' ability to use evidence to form explanations impact their content mastery?	Pre- and Post-Survey	Student Artifacts (conclusion examples)	Student Interviews
Subquestion 1: If students practice using an outline based on CER in their scientific writing, will it improve their use of evidence in conclusions?	Pre- and post-Assessment	Student Artifacts (conclusion examples)	Pre- and Post-Survey
Subquestion 2: In what ways does implementing a conclusion writing framework and practice analyzing data improve students' ownership of the learning process?	Pre- and post - Survey	Student Interviews	Teacher Field Notes

DATA AND ANALYSIS

In order to answer my research questions, data was collected over a six-week period in two units, rocks and minerals (Unit 1) and weathering (Unit 2). My main focus question "How will students' ability to use evidence to form explanations impact their

content mastery?” was addressed by collecting data in the form of a pre- and post-survey, student artifacts throughout the units, and student interviews. A pre- and post-survey was used to determine if the framework helped organize their thoughts and improved conclusion writing. Student artifacts were analyzed to determine if they were incorporating evidence into their writing and understanding the material. Student interviews were utilized at the end of the intervention to determine if the students felt their understanding of the material was improved by using the framework.

A survey was given to all students at the beginning and end of the implementation period. All statements were scaled on a one to five scale, one being strongly disagree and five being strongly agree. During the post-survey, one student had technical difficulties, resulting in having his or her responses submitted twice. As the surveys were anonymous it was difficult to tell which of the responses were duplicates, so the post-survey has one extra “student” for a number of answers. The statements on the student survey associated with my focus question are summarized in Table 2.

Table 2
Pre- and Post-Survey Averages (N=15)

Survey Statement	Pre-Survey Average	Post-Survey Average
I feel confident in my ability to write a scientific conclusion.	3.3 ± 0.7	3.3 ± 0.6
The Claim Evidence Reasoning framework does not improve my conclusion writing.	2.8 ± 1.0	2.4 ± 1.1
The Claim Evidence Reasoning framework improves my confidence in my conclusion writing ability.	3.2 ± 0.9	3.5 ± 1.0

Overall, there was not much of a change in students’ feelings toward their ability

to write a conclusion. The individual responses to two of these statements were graphed.

The statement “The Claim Evidence Reasoning framework helps me organize my thoughts” was used as an indicator of students’ understanding of the material. Figure 1 summarizes the pre- and post- survey results for this statement.

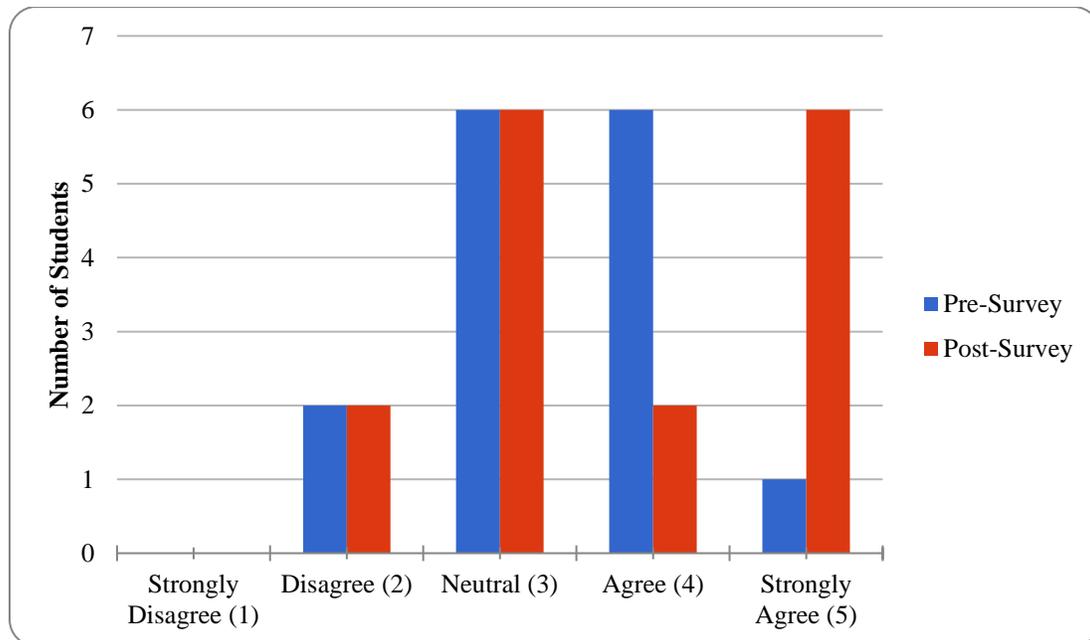


Figure 1. Individual responses for pre- and post-survey statement “The Claim Evidence Reasoning framework helps me organize my thoughts”, ($N=15$).

There was no change in the number of students’ that disagreed with (2) and felt neutral about (3) this statement. The number of students who agreed with this statement decreased from six to two, while the number of students that strongly agreed with this statement increased from one to six. While it was impossible to determine which students shifted their responses in this anonymous survey, it was interesting to note that the shift suggested that students who agreed initially were likely to see even more value in the framework after explicit instruction and practice. The students that disagreed with this statement may have been students that initially disagreed and were not engaged with

the material because of their initial feelings toward the framework. To confirm or deny whether this was an example of confirmation bias, future surveys could be designed to measure changes in individual responses while remaining anonymous.

The statement “The Claim Evidence Reasoning framework improves my confidence in my conclusion writing ability” was also used as an indicator for students’ understanding of the material. Figure 2 summarizes the pre- and post- survey results for this statement.

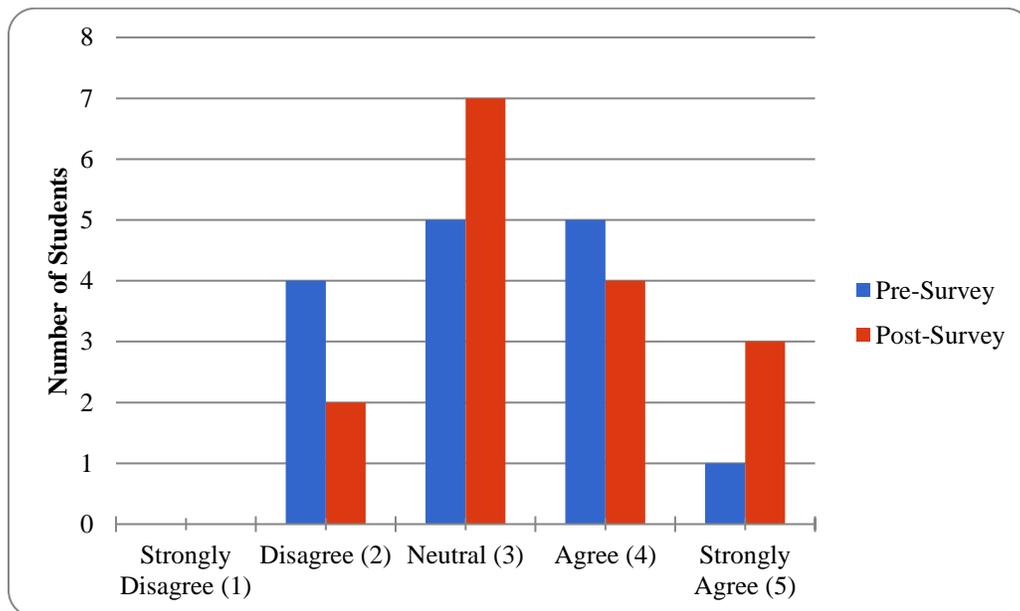


Figure 2. Individual responses for pre- and post-survey the statement “The Claim Evidence Reasoning framework improves my confidence in my conclusion writing ability”, ($N=15$).

The data shows that the number of students who disagreed with this statement decreased from four to two. The number of students who felt neutral about this statement increased from five to seven. The number of students who agreed with this statement decreased from five to four, while the number that strongly agreed increased from one to three. There was an overall trend towards more confidence in their conclusion writing

abilities, which indicates that they felt comfortable with the concepts. Students' connection of the framework to the more concrete idea of conclusion writing ability may have generated more accurate responses than the first survey statement, which connected the framework to the more abstract idea of organizing one's thoughts.

Additional on the pre- and post- survey the students could pick one statement to comment on. The students that chose to leave comments associated with these statements mostly had positive statements to express. For example, one student stated "The Claim Evidence Reasoning framework always helps my to organize my thoughts and ideas. It is harder to just write it out on a sheet of paper than first doing it on the CER framework." One student still expressed a desire to improve and stated "I need more help writing my claim and reasoning because it is hard for me to get the right details." indicating there was still some confusion.

The student artifacts were analyzed to determine if the use of this evidence helped them understand the content. Throughout the units the students practiced with the CER framework to review the main concepts being taught. For example, during the rock cycle unit, students had to support a claim that stated "Metamorphic rocks were formed from the other two types of rocks." This helped review the information with the students and determine if there were any misconceptions. To determine if there was a correlation between the students' work, the CER framework, and their content mastery, the CER grade for each unit and the final assessments for each unit were compared.

For Unit 1, the assessment was a test at the end of the rocks and minerals unit. Over the course of this unit, students completed multiple CERs that were graded based on

the rubric in Appendix D. Tests grades were on a scale of 100, so the test grades were correlated to the following scale: 0-60 = 1; 60-75 = 2; 75-90 = 3; 90-100 = 4 for comparison to the CER grades. Figure 3 summarizes the average CER grades compared to the assessment for Unit 1.

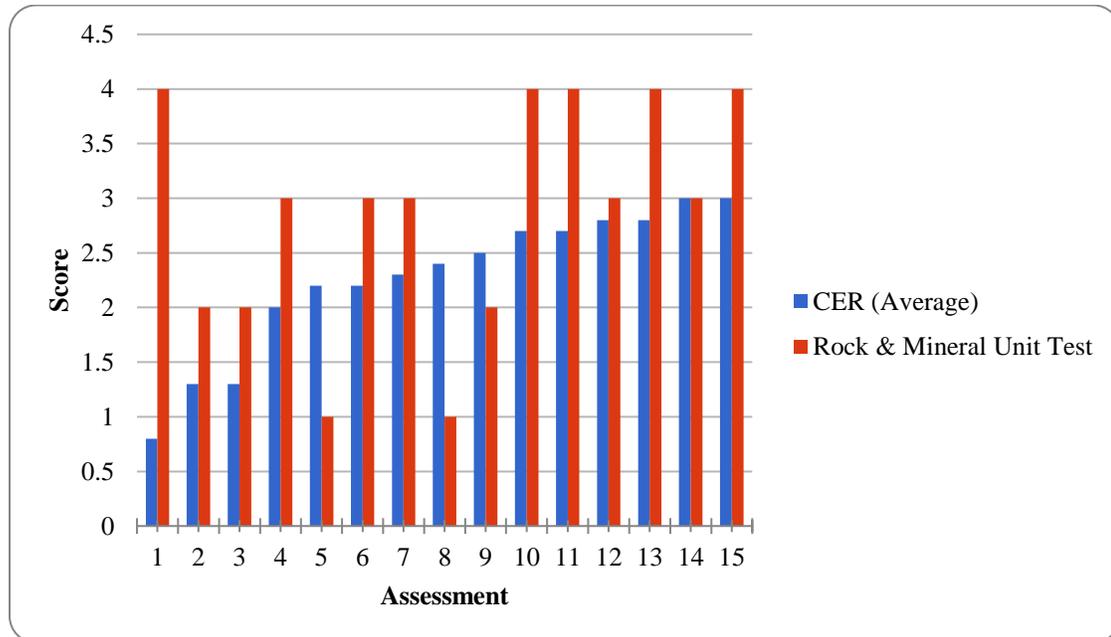


Figure 3. Comparison between CER artifacts and assessments during Unit 1, ($N=15$).

Overall, there was a general trend that as the CER average increased the student did better on the assessment, but no strong correlation. Results that did not fit the trend included five students who received similar test scores while their average CER grades ranged from a 2 to a 3. One student put minimal effort into the CER, but did perform very well on the test. Three students performed better on the CERs than they did on the test.

After the completion of Unit 2, weathering and erosion, students had to write a lab report based on an investigation they had designed. Students used the CER as a outline

for their conclusion on their lab report in Unit 2 and again the CER was graded based on the rubric in Appendix D. Note that two students did not complete the CER as an outline. The lab grade used for comparison was based off the conclusion section of students' lab reports. The CER rubric was used to grade the conclusion section of these reports.

Figure 4 summarizes the average CER grade compared to the assessment for Unit 2.

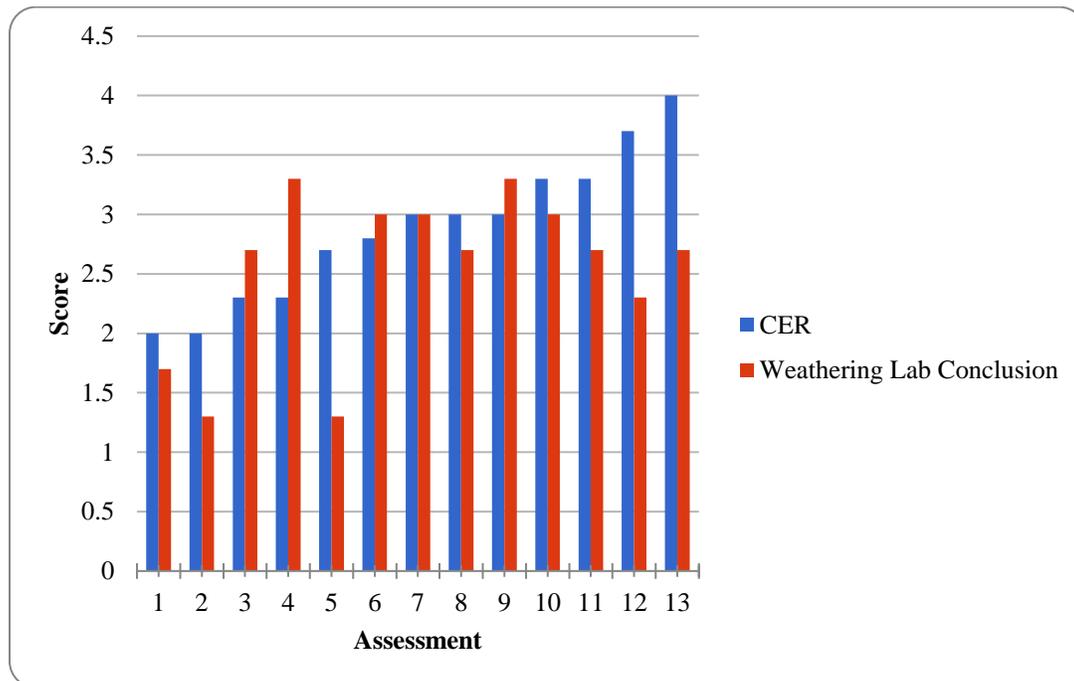


Figure 4. Comparison between CER artifacts and assessments during Unit 2, ($N=13$).

Again, there was a general trend of increasing grades on the CER correlating to a higher score on the conclusion, but it was not a strong correlation. Two students scored very well on their CER, but did not use the CER as an outline to help write the conclusion. Therefore the conclusions were missing a number of requirements, so there was a large difference between their CER and conclusion grade.

Interviews of four students consisted of questions in Appendix G. The responses collected in the interviews to the CER framework were primarily positive. The students'

all seemed to understand the purpose behind the CER framework. One student stated “I am not very good at writing, it is supposed to help us take things and use evidence to find the answer”. The majority of students agreed that reasoning was the most difficult portion of the framework because the “claim was used before in literacy and the evidence was straightforward, we just used data”.

As far as impacting their mastery of the content, the students all believed that the framework helped them organize their thoughts and improved their writing in science. One student stated that it “Yeah, it helps me to focus on my claim and find supporting evidence. It is like writing a constructed response in science”. Another student appreciated “being able to look at it all to see how it came together and how it fit to help prove your claim”. One student did state that there were times when they were “frustrated” and just completed the graphic organizer to have it done.

My first sub-question “If students practice using an outline based on CER in their scientific writing, will it improve their use of evidence in conclusions?” was addressed by collecting data in the form of pre- and post- assessments, student artifacts throughout the units, and pre- and post-survey. A pre- and post- assessment was used to compare and measure students’ gain in using evidence and reasoning to support their conclusions. Student artifacts were analyzed to determine if they were incorporating evidence into their writing. Student interviews and surveys were utilized at the end of the intervention to determine if the students felt they could incorporate evidence into their work successfully.

The pre- and post-assessment given measured students ability to understand and

use evidence and reasoning within their argument. All students made gains between the pre- and post-assessment. The biggest gains were in stating clear claims and using appropriate and sufficient evidence. Students still struggled with using reasoning appropriately in the post-assessment. Five students made gains under ten points. While one student's improvement was only four points, the discussions and work that was completed in the classroom suggested a deeper understanding of the material, so there was some question as to how much effort was put into the post-assessment. One student already had a good understanding of the material, so while the improvement was relatively low, the final score was one of the highest in the class. The levels of effort on the post-assessment were questionable for the three other students whose improvements were on the low end (below 10). The students who made the largest gains on the assessment (greater than 29 points) had a range of abilities, indicating that the framework was beneficial to students who have consistently struggled in class as well as students who have consistently done well in class. Figure 5 summarizes the pre- and post-assessment results.

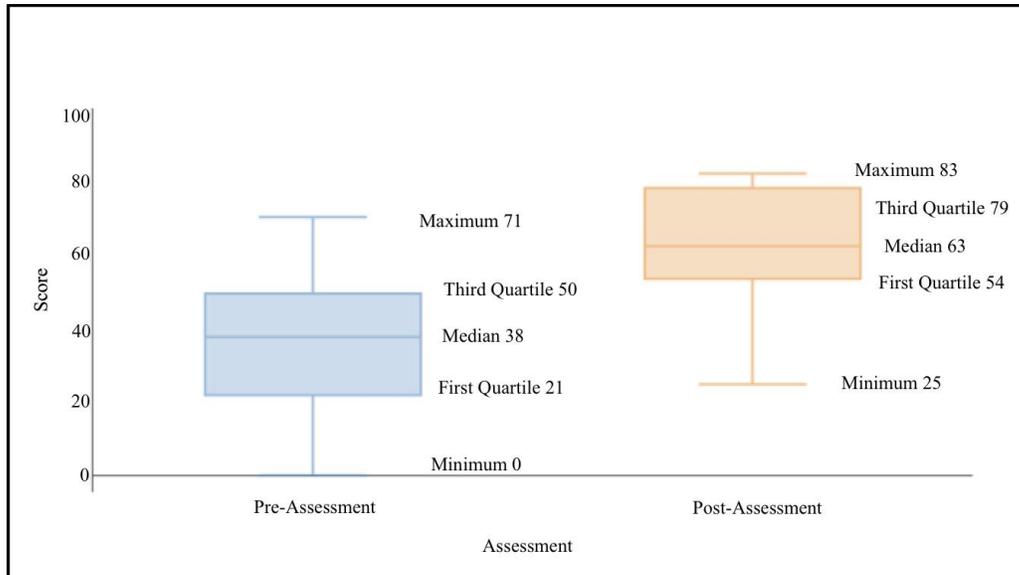


Figure 5. Pre-test and post-test score distribution, ($N=15$).

The pre-assessment had a Mean score of 36.9, with a standard deviation of 17.9. The post-assessment average was 63.1 with a standard deviation of 17.1. The difference between Pre-and Post- surveys was significant, $t(28)=3.9812$, $p=.0004$. The significance of this gain was that the students' improved their ability to use evidence to support their claims. The improvement between the pre- and post- assessment demonstrated that the students were using evidence to support their claims.

The artifacts used during these units were journal entries in which students' wrote summaries, projects, and a lab report. The evidence within each of these artifacts was graded based on the CER rubric. Students could achieve a 4 under evidence if the used sufficient and appropriate (relevant) evidence. Figure 6 summarizes the average evidence score for assessments throughout the intervention.

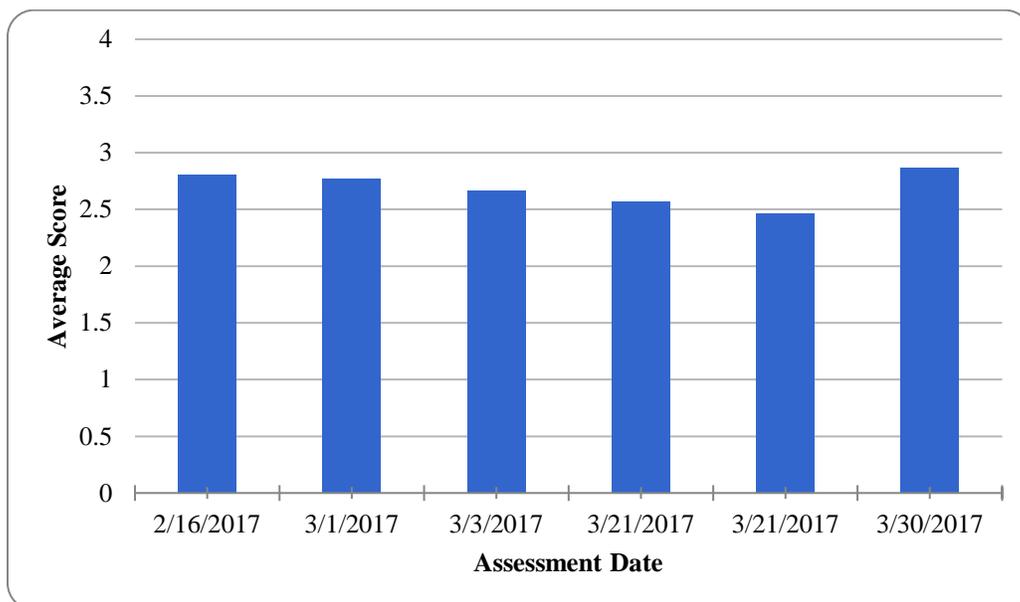


Figure 6. Use of sufficient and appropriate evidence in student work over time, ($N=15$).

There were no apparent trends in students' use of evidence within their conclusions. Their use of sufficient and appropriate evidence was heavily dependent on their understanding of the content. The highest average score for use of evidence was for the weathering lab conclusion (assessment data of 3/30/2017). This should be expected as it was a final project while some of the other CERs (assessment dates of 3/1/2017 and 3/21/2017) were journal entries completed within a class period.

Throughout the units, the majority of the students used appropriate evidence, but it was not always sufficient. Some students used incorrect or not relevant evidence, especially when they did not understand the material. A few times students' were not necessarily providing evidence that supported their stated claim.

The pre- and post-survey had a number of statements included to gauge students' perception of their ability to use evidence and write a conclusion. Table 3 below summarizes the average results for the statements on the survey associated with the first

sub-question. Again, there seemed to be very little change between the pre- and post-survey and the standard deviation tended to be fairly high indicating that the responses were widespread.

Table 3
Pre- and Post- Survey Average for Sub-Question One

Survey Statement	Pre-Survey Average	Post-Survey Average
I feel confident in my ability to support a claim with evidence.	3.8 ± 1.0	4.1 ± 0.6
I feel confident in my ability to tie my evidence to a claim with reasoning.	3.5 ± 0.7	3.5 ± 0.9
When I have to write a conclusion with supporting evidence, I am nervous.	2.7 ± 0.7	2.4 ± 1.1
It is difficult for me to use reasoning that relates my evidence to my claim.	2.5 ± 0.6	2.4 ± 0.9
The Claim Evidence Reasoning framework helps me organize my thoughts.	3.4 ± 0.8	3.8 ± 1.1

Note. ($N=15$)

The individual responses to two of these statements are graphed. On the survey, the statement “I feel confident in my ability to support a claim with evidence.” was used as an indicator of students’ use of evidence within their writing. Figure 7 summarizes the pre- and post- survey results for this statement.

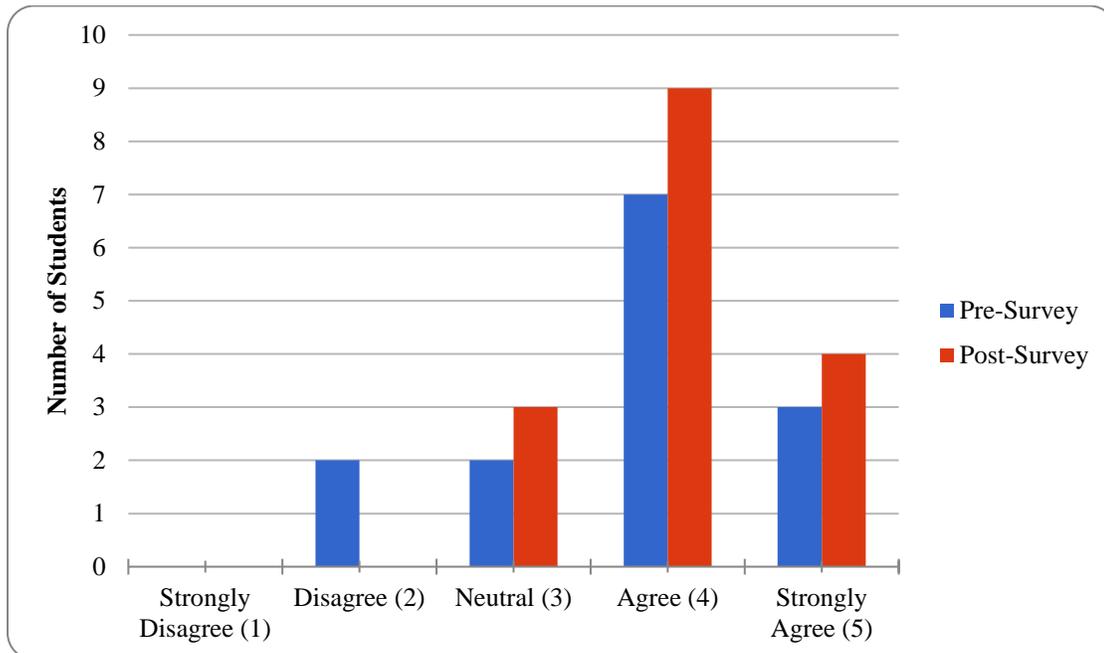


Figure 7. Individual responses for pre- and post-survey statement “I feel confident in my ability to support a claim with evidence”, ($N=15$).

One student did not provide a response to this statement during the pre-survey. During the pre-survey, two students disagreed that they felt confident about using evidence to support a claim, while no students disagreed during the post-survey. The number of students that felt neutral about their ability increased by one. The number of students that agreed increased by two and those that strongly agreed increased by one. Overall there was a shift towards feeling more comfortable using evidence in their conclusion writing.

The statement “When I have to write a conclusion with supporting evidence, I am nervous.” was used as an indicator of how comfortable the students’ felt using evidence within their conclusion writing. Figure 8 summarizes the pre- and post- survey results for this statement.

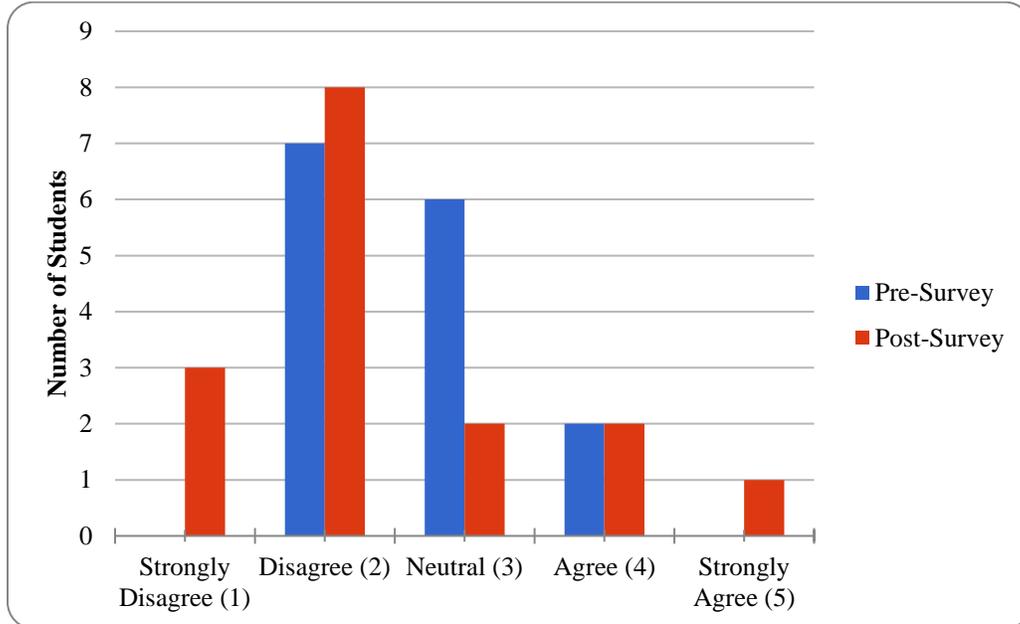


Figure 8. Individual responses for pre- and post-survey statement “When I have to write a conclusion with supporting evidence, I am nervous”, ($N=15$).

One student strongly agreed that they were nervous about using evidence in their conclusions on the post-survey, while none felt that way on the pre-survey. This may have been a misunderstanding of the statement, since it was posed as a negative or the students may not have realized what went into conclusion writing prior to the intervention. There was no change in the number of students (2) that agreed with this statement, indicating they felt nervous about conclusion writing. The number of students that felt neutral about this statement increased by 3, while the number of students who disagreed and strongly disagreed (whose confidence in conclusion writing increased) increase by one and three, respectively. There was a shift towards feeling capable of using evidence and reasoning within a conclusion, but this shift was not necessarily translated into confidence in conclusion writing ability.

On the pre-survey one student stated “When I write a conclusion I am nervous,

because I am always nervous because I am not a good writer and I want to get a good grade, so I am always nervous.” There was not a similar statement on the post-survey. The student could have chosen to focus on another statement or using the framework may have helped their confidence in their conclusion writing. On the post-survey, one student noted that “I feel very confident in writing evidence for a claim because I used to do it a lot.”

My second sub-question “In what ways does implementing a conclusion writing framework and practice analyzing data improve students’ ownership of the learning process?” was addressed by collecting data in the form of pre- and post- survey, student interviews, and teacher field notes. The pre- and post- survey included statements used to compare and measure students’ attitude towards science and argument writing in their lives. Student interviews were utilized at the end of the intervention to determine how the students felt about their ability to write a conclusion and how science applies to their daily lives. Teacher field notes were recorded during and after class, noting students’ interactions and engagement with the material.

A number of statements in the pre- and post-survey were designed to determine how students felt that science and argument writing connected to their daily lives. The hope was that this connection would promote student buy-in and ownership of their learning process. Table 4 below summarizes the average results for the statements on the survey associated with the second sub-question.

Overall there was little change in responses to how students felt about argument writing in their future, but there seemed to be a shift towards not thinking that science

and scientific writing could be useful. The individual responses to two of these statements were graphed. The statement “Making decisions can be difficult without reliable evidence” was used to gauge how necessary accurate information was to students’ while they were making decisions. Figure 9 summarizes the pre- and post-survey results for this statement.

Table 4
Pre- and Post- Survey Average for Sub-Question Two

Survey Statement	Pre-Survey Average	Post-Survey Average
The ability to make a strong argument will be very important to my career.	3.6 ± 0.8	3.7 ± 0.8
I think argument writing is important to my life.	3.3 ± 0.8	3.3 ± 1.0
In the past, I have not enjoyed science classes.	2.5 ± 1.4	3.1 ± 1.2
I receive good grades on science tests and quizzes.	3.2 ± 0.7	3.2 ± 1.0
Argument writing interests me.	2.2 ± 1.0	2.2 ± 1.2
Making decisions can be difficult without reliable evidence.	4.2 ± 0.8	3.7 ± 1.2
Learning science allows me to clearly explain what I am thinking.	3.3 ± 0.7	2.7 ± 0.8
Making good decisions is a scientific process.	3.5 ± 0.6	3 ± 1.0

Note. (N=15)

Students generally agreed or strongly agreed in both the pre- and post-survey when asked if making decisions was difficult without reliable evidence. Three fewer people strongly agreed and one less person felt neutral in the post-survey. Three more people agreed, while 2 people who had not disagreed with the statement in the pre-survey strongly disagreed with the statement during the post-survey. While the majority of

students agreed that using reliable evidence was useful in making decisions, there was a shift towards some students not seeing a benefit.

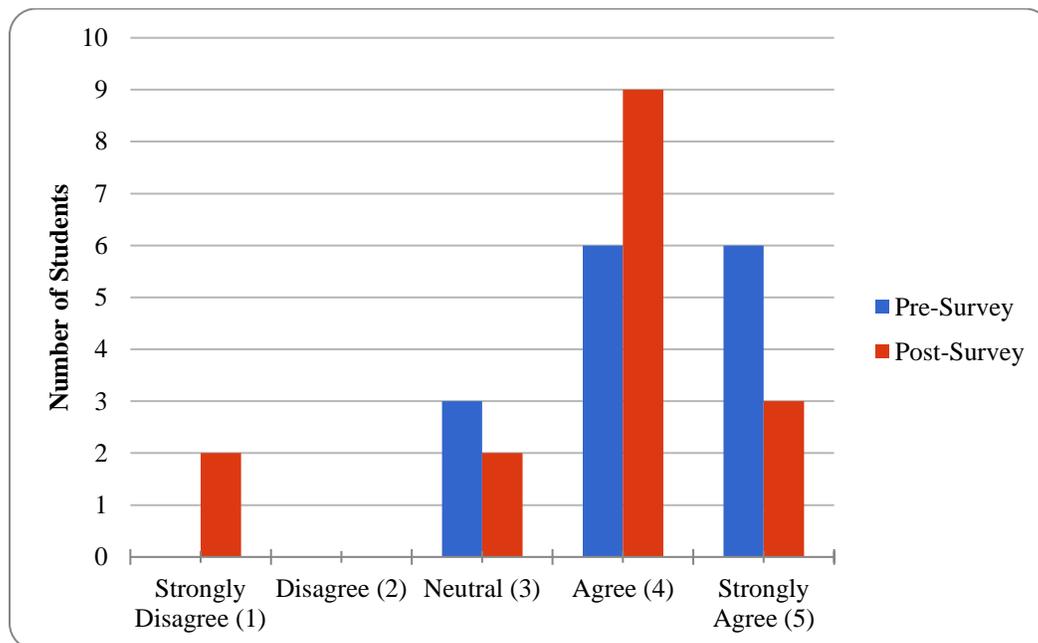


Figure 9. Individual responses for pre- and post-survey statement “Making decisions can be difficult without reliable evidence”, ($N=15$).

The statement “Making good decisions is a scientific process.” was used as an indicator to see if students saw the value of this type of argument writing in their daily lives. Figure 10 summarizes the pre- and post- survey results for this statement.

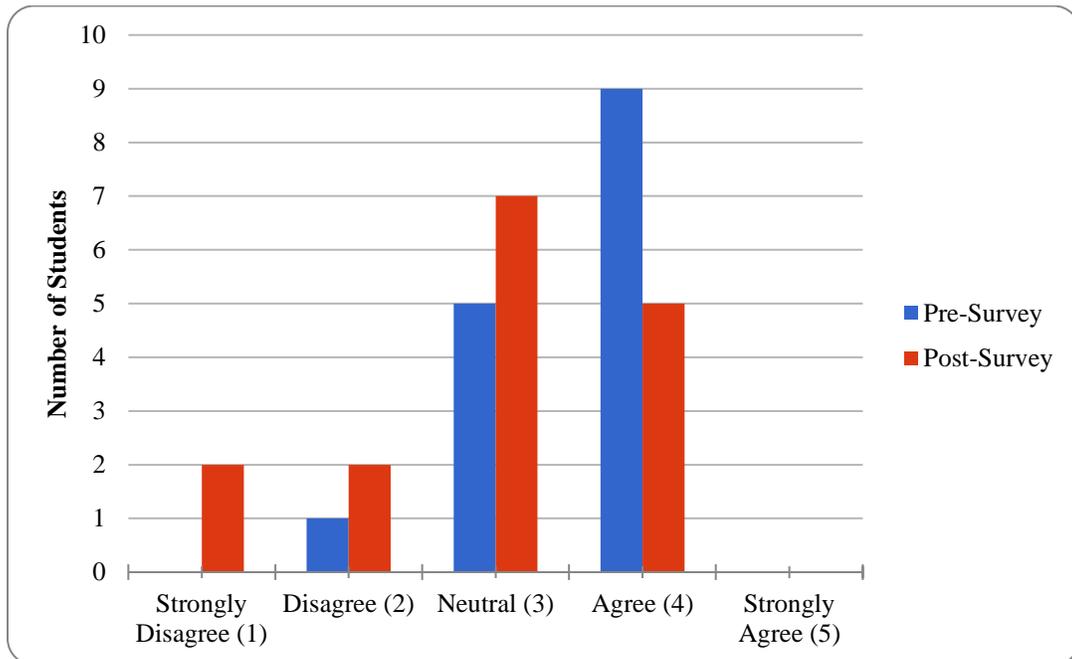


Figure 10. Individual responses for pre- and post-survey statement “Making good decisions is a scientific process”, ($N=15$).

Again, two students strongly disagreed with this statement on the post-survey whereas none strongly disagreed on the pre-survey. One additional student disagreed with this statement on the post-survey for a total of two. The number of students that agreed with this statement decreased from nine to five, while the number that felt neutral increased from five to seven. A similar shift was seen on this question, as students’ saw less of a correlation between using scientific processes as being helpful in making a good decision.

These results indicate that the CER framework did not increase students’ buy in with regards to science or argument writing being important in their everyday lives. As part of the survey, many students chose to make a statement about making a decision and how it related to science. Their statements ranged from thinking science was important

to unimportant in their decision making. One stated “Making Decisions can be difficult without reliable evidence. I chose strongly agree because it is hard to get an answer and write about it if there is no evidence. Then it would just be opinionated.” One student stated they were “not sure if I will need to be able to make a strong argument in my future career” so they were neutral about that statement. Another student stated “I don't think that argument writing is important to my career because not all jobs have to deal with argument writing.” The number of students that do not find science relevant to their lives coincided with the number of students who were unengaged in the classroom.

Questions were asked during the student interviews to determine if the CER framework increased their interest in science and how students' felt science tied into their lives. When students were asked “Are there certain times when science seems more relevant/connected to the rest of your life?”, two students answered no, one student answered probably and gave an example of “repairs to things”, and the fourth student answered yes. This student stated that “everything is more scientific and that you can find more connections than in other subjects”. Overall the relevancy of science depended heavily on the content.

Students were also asked “Did using the CER framework increase your interest in the subject matter?” Two students stated that it did not really increase their interest in the subject matter, with one of those students following up by stating that “it is the same as writing it down on paper, just more organized”. The third student stated that helped sometimes. The fourth student stated that it did help because “you could understand it better. Instead of moving on and maybe forgetting about it having to focus on it and

write it down helped you “see” it in the end.”

Teacher field notes were recorded throughout the intervention. In general, there were a number of motivated students within this classroom along with a handful that require prompting to stay on task and to keep up with their work. In the beginning of the intervention, some students stated that they were bored with the framework while they did have an interest in the material. At the beginning of the intervention it was noted that the students’ struggled to incorporate evidence into their work. During the second week of the intervention, the majority of the students’ were attempting the work and staying on target. There were three students (of 15) that were not completing all of the CER work and missing other materials within the classroom. The use of evidence for this section (minerals) was improving and some students were beginning to incorporate scientific language in their reasoning. Some students were using facts as their evidence instead of the data that had been collected in class.

During week 3 of the intervention students completed a research project related to mining. It was noted that during this project it was difficult to motivate some students, while some did the entire project on their own. Eight students took the initiative about many pieces of the project. One additional student needed a little guidance and prompting, but completed the project nicely. One student did not focus in class then requested more time on the project. Two students struggled but did try to work on the project, while three students were difficult to keep on track. While writing the CERs during this week, three students had a good discussion about inconclusive evidence and how that should be discussed. Another student could be heard passing along what I had

stated that “we want to use the data as evidence”.

The students seemed to struggle a lot more with the information the fourth week. It was noted that the students’ may have been lacking necessary background information to draw some conclusions correctly. A review of the CERs that were completed highlighted the need to revisit certain information within the unit. During this week, one student that typically did not complete all their work seemed to be on track. There was still limited buy in from the two other students who typically do not complete work.

During week five, the CER framework was used to introduce a weathering lab. The class went outside and made observations and the students were asked to address the question “How does water affect the Earth’s surface?” This seemed like a good way to introduce the project and gave the students’ a way to organize their background information. All but one student completed the pre-CER. Overall, the pre-CERs seemed to show student interest but showed little evidence of the students making a connection to the properties of water and how this erodes so this was explicitly reviewed as the students’ worked on their investigations.

The last week of the intervention the students used the CER as a guideline to write their conclusion their weathering investigation lab report. It was noted that nine students worked hard throughout the project. One of these nine students worked hard but struggled understanding a lot of the material so was not completely invested, but still wanted to do well. Four students worked hard fifty to seventy-five percent of the time. A few of these students wanted more time for the investigation, but these students also admitted to completing no work outside of class and not using class time efficiently. The

attitude of one student in particular seemed to be shifting. This student wanted to do better and was volunteering to come in to work on material, but still spent a lot of time and energy trying to avoid the actual work. Two students still did not seem to buy in at all to the material.

Throughout the six weeks of the intervention half the class was engaged and working with little to no prompting. Four students seemed to have good days and bad days, where on the good days they would take responsibility for their work. Of the three remaining students, there seemed to be one whose attitude shifted away from completing little to no work towards taking more responsibility. There was little change in the attitude of the two remaining students.

INTERPRETATION AND CONCLUSION

With regards to the focus question, there was a general trend that students who did better on the CERs, performed better on the assessment, but no strong correlation. The students that felt that the CER framework helped them organize their thoughts may have seen those translated to higher scores on the assessment. Some students did not buy into the material or the CER framework, which may be why there was not a strong correlation between the CERs and concept gains. As McNeill and Krajcik (2012) stated, the hope was that the framework would provide a good baseline for the students' to build upon. In this regard, a number of students did appreciate being able to organize their thoughts, as noted in the survey and interviews, and used it as a reference.

There was a shift towards feeling capable of using evidence and reasoning within a conclusion, but this shift was not necessarily translated into confidence in conclusion

writing ability. In addition, there was a shift in thinking that the framework helped them with their conclusion writing ability, but again this did not translate into confidence in their ability to write a conclusion. This correlates well to a study performed by McCright (2012) that showed students seeing larger gains in understanding within inquiry based learning, but not being more confident in their learning ability.

With regards to the first sub-question, the use of evidence was found to be dependent on the students' understanding of the material, but there was a slight shift towards students feeling more confident in their ability to use evidence within their conclusions. It was shown that being able to form an explanation and analyze their data to draw conclusions allowed the students to make more content gains. If students could use the framework to help them understand the material, then their background knowledge in turn would increase and improve their ability to make new and stronger connections to new content. During student interviews there did seem to be a consensus that the framework helped students organize their thoughts. One student felt that the framework provided a good reference to review the information. There was no clear connection between students' ability to organize their thoughts and content gains.

The benefits of practicing observations before implementing an inquiry project were noted in a study by Park Rogers (2009), and students in the classroom practiced these observations prior to implementing their final inquiry project during the intervention. This was useful within the inquiry project and gave students good background information to begin their projects and a point of reference while working on their conclusions. Another study by Saglam, Karaaslan, & Ayas (2014) that was

incorporated into the lessons was related to explicitly teaching how to write a scientific explanation. The students were given multiple examples, practice and review throughout the intervention in an effort to explicitly teach about scientific explanations.

With regards to the second sub-question, students may not have taken more ownership of the learning process, but I believe that outlining their evidence gave them a solid understanding of the intent behind processes and information. This helped them not only in deepening their understanding, but also in being able to retain information or deduce the correct answer if given information. Students still found the reasoning portion of the framework difficult and struggled connecting their evidence to their claim. Friedel, et al (2008) found that directly teaching critical thinking helped with this prospect. While I did try to walk through examples and give feedback, this was an area in which students' still struggled. This study only lasted for a short period of time, but did introduce a solid foundation of what was expected in a scientific explanation. For the true gains to be seen, the student needs to be able to build on their previous knowledge and make new connections.

Overall, implementing the conclusion-writing framework made little impact on students' engagement with the material. It was thought that if students understood the material better with the help of the framework, there would be more engagement with the material. While the outline may have helped one student improve on work completion, there seemed to be little change in the overall attitude of the class.

VALUE

Using the CER framework as a formative assessment in my classroom was a

really useful approach to help students be organized, as well as breakdown what areas still need to be worked on. Using the framework allows them to organize their thoughts around the concepts and provide an opportunity to see what students are explicitly thinking in their reasoning. For instance, instead of giving a student a blanket grade on their conclusion, it provides the ability to breakdown the feedback between the three sections and focuses the student on where they need to improve.

While I think that having the students find evidence to support a claim was a great way to help make sense of the content, I think the journal reflections and the CER graphic organizers used throughout the units provided useful information about misconceptions that the students had. For instance, while trying to address the claim of whether or not all rocks had to be igneous at one time, a misconception about the rock cycle came forward. The students did believe that all rocks had to be igneous at one point, but the reasoning for a number of students had to do that the rocks moved through the rock cycle in a specific manner and they all had to eventually become igneous in that manner. These insights to the misconceptions helped me realize what needed to be retaught or discussed for clarification.

I had not consistently used a framework or graphic organizer in the past and I found this to be helpful. Students knew what was expected on the graphic organizer and the framework could just be referenced and incorporated into writing. The common language made quick writing tasks straightforward to incorporate and referencing areas of focus to improve student work an easier task.

I will continue to use the CER framework as a way to improve students' ability to

write a conclusion and help them organize their thoughts. As discussed above, I may use it as more of a formative assessment and a method to identify common misconceptions.

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APPENDICES

APPENDIX A
CONSENT FORMS

Subject Consent Form for Participation in Human Research at Montana State University

“Forming Explanations from Evidence Using the Claim-Evidence-Reasoning Framework”

Dear Parents or Guardians,

Your child is being asked to participate in a research study in the earth science classroom to determine if using the claim-evidence-reasoning (CER) framework improves students’ ability to write scientific explanations. The purpose of the study is to improve students’ scientific writing and analysis of data, which will hopefully lead to an increase in understanding of concepts. Students in the spring earth science course will be included in the research. Joe Debonis has approved this study.

Participation is voluntary. The procedures will include regular activities, lessons, and labs with an emphasis on analyzing data/observations within the CER framework. During the study, various forms of data will be collected to determine whether the CER intervention was successful. Possible types of data I will collect include samples of student work (labs, journals, worksheets), surveys/questionnaires, interviews, observations, and test scores. If you agree to participate, the only additional procedures for your child (above and beyond normal classwork) will be the survey and interviews. Survey participation is voluntary and your child can choose to not answer any questions he or she does not want to answer and/or stop at any time.

There are no foreseen risks to this study. Only I will have direct access to your child’s identity and to information that can be associated to your child’s identity. You may contact me at any time with questions regarding your child’s participation. My email is Johanna.Traut@rswsu.org and my phone number is 287-5861 x260.

Use of data from your child is voluntary and will have no impact on your child’s grade. You may contact me at any time if you do not wish to have your child’s data included in the study. Withdrawal will have no impact on your child’s grade. Students will be given an assent form in class to explain the process and ask their permission. A summary of the findings can be shared upon request.

I have read the above and understand the discomforts, inconvenience and risk of this study. I _____ (*name of parent or guardian*), related to the subject as _____ (*relationship*), agree to the participation of _____ (*name of subject*) in this research. I understand that the subject or I may later refuse participation in this research and that the subject, through his/her own action or mine, may withdraw from the research study at any time. I have received a copy of this consent form for my own records.

Parent or Guardian Signature: _____ Date: _____

Investigator: _____ Date: _____

Student Assent Form
Authorization to Serve as a Research Participant

Dear Student,

I will be conducting a study in our classroom to determine if using the claim-evidence-reasoning (CER) framework improves students' ability to write scientific explanations. I am asking permission to use the data I collect from you during this process. Participation in this study involves only regular classroom activities. You may ask me questions at any time about this study. The principal of the school has approved this study.

The purpose of the study is to improve students' scientific writing and analysis of data, which will hopefully lead to an increase in understanding of concepts. The study will take place in my classroom, Room 301, and last for approximately five weeks. The procedures will be regular activities, lessons, and labs with an emphasis on analyzing data/observations within the CER framework. During the study, I will collect various forms of data to determine whether the CER intervention was successful. Possible types of data I will collect include samples of student work (labs, journals, worksheets), surveys/questionnaires, interviews, observations, and test scores).

I will not include your name in any report about this study. You have the right to ask me not to include your data in the study or to tell me later if you no longer want your data included. Whether or not you choose to participate in the study will have no impact on your grade.

If you agree to let me use your data in the study, please print and sign your name below.

I give permission for my data to be used in this study.

Student Printed Name

Student's Signature

Date

APPENDIX B
ONLINE STUDENT SURVEY

1. I feel confident in my ability to write a scientific conclusion.

Strongly Agree Agree Neutral Disagree Strongly Disagree

2. I feel confident in my ability to support a claim with evidence.

Strongly Agree Agree Neutral Disagree Strongly Disagree

3. I feel confident in my ability to tie my evidence to a claim with reasoning.

Strongly Agree Agree Neutral Disagree Strongly Disagree

4. I feel confident in my ability to incorporate scientific vocabulary into my reasoning.

Strongly Agree Agree Neutral Disagree Strongly Disagree

5. When I have to write a conclusion with supporting evidence, I am nervous.

Strongly Agree Agree Neutral Disagree Strongly Disagree

6. It is difficult for me to use reasoning that relates my evidence to my claim.

Strongly Agree Agree Neutral Disagree Strongly Disagree

7. The Claim-Evidence-Reasoning framework helps me organize my thoughts.

Strongly Agree Agree Neutral Disagree Strongly Disagree

8. The Claim-Evidence-Reasoning framework does not improve my conclusion writing.

Strongly Agree Agree Neutral Disagree Strongly Disagree

9. The Claim-Evidence-Reasoning framework improves my confidence in my conclusion writing. Strongly Agree Agree Neutral Disagree Strongly Disagree

10. The ability to make a strong argument will be to very important to my career.

Strongly Agree Agree Neutral Disagree Strongly Disagree

11. I think argument writing is important to my life.

Strongly Agree Agree Neutral Disagree Strongly Disagree

12. In the past, I have not enjoyed science classes.

Strongly Agree Agree Neutral Disagree Strongly Disagree

13. I receive good grades on science tests and quizzes.

Strongly Agree Agree Neutral Disagree Strongly Disagree

14. Argument writing interests me.

Strongly Agree Agree Neutral Disagree Strongly Disagree

15. Making decisions can be difficult without reliable evidence.

Strongly Agree Agree Neutral Disagree Strongly Disagree

16. Learning science allows me to clearly explain what I am thinking.

Strongly Agree Agree Neutral Disagree Strongly Disagree

17. Making good decisions is a scientific process.

Strongly Agree Agree Neutral Disagree Strongly Disagree

Choose one of the statements above and explain your choice.

APPENDIX C
PRE-/POST-TEST

Name: _____

CER Pre-/Post Assessment

1. Define claim and give an example.
2. Define evidence and give an example.
3. Define reasoning and give an example.

The Lunchroom Murder

On an otherwise uneventful Thursday afternoon police heard a shot inside Ernie's Lunchroom, rushed in, and found the scene shown in Figure 1.4.

They identified the body as that of a prominent racketeer named Fannin. Ernie, who is both the owner and only employee, had only one fact to tell: the murderer had leaned against the wall while firing at point-blank range. The imprint of his hand is in clear view. The cash register has just been rung up at \$8.75.

This is a difficult case. Your investigative team must attempt to determine which of the people in the lunchroom killed Fannin. You will have to observe the details carefully.

There is enough evidence to help you explain most of what happened. In working out the solution, consider the following questions.



FIGURE 1.4 "The Lunchroom Murder"

4. Did customers B, C, and D know each other? What are the evidence and reasoning?
5. How do the three customers differ in their habits or ways of doing things? What is the evidence and what is the reasoning?
6. Which set of footprints are Ernie's? What is the evidence? What is the reasoning?
7. To whom do the set of footprints marked X belong? How do you know?
8. Who killed Fannin? How do you know? Outline all the evidence and all of the reasoning necessary to support this claim.

Examine the following data table:

	Density	Color	Moh's Hardness	Streak
Mineral 1	2.65 g/cm ³	Colorless, clear	7	Colorless
Mineral 2	2.7 g/cm ³	White	1	White
Mineral 3	3.4 g/cm ³	Pink	8	Colorless
Mineral 4	2.65 g/cm ³	Purple	7	Colorless

Write a scientific explanation that states whether any of the minerals are the same substance.

APPENDIX D
CLAIM EVIDENCE REASONING RUBRIC

	4 points	3 points	2 points	1 points
<p>CLAIM</p> <p>The writer makes a statement or conclusion that answers the original question or problem.</p>	<p>Compelling Claim</p> <p>Claim is clear and scientifically sound and directly related to the question</p>	<p>Credible Claim</p> <p>Claim is clear and scientifically sound and closely related to the question</p>	<p>Weak Claim</p> <p>Claim is implied but not clearly state, reveals partial understanding and has some relevance to the question</p>	<p>Inadequate Claim</p> <p>An attempt at a claim is made, but is minimally accurate</p>
<p>EVIDENCE</p> <p>The writer supports the claim with relevant evidence using credible sources and demonstrating an understanding of the topic or context.</p>	<p>Appropriate & Sufficient Evidence</p> <p>Evidence is appropriate* and sufficient</p>	<p>Appropriate Evidence</p> <p>Evidence is appropriate* and may be sufficient</p>	<p>Relevant Evidence</p> <p>Evidence is accurate but only somewhat relevant* and may be sufficient</p>	<p>Inadequate Evidence</p> <p>Evidence is either accurate or somewhat relevant, but not both* and is not sufficient</p>
<p>REASONING</p> <p>It shows why the data and information counts as evidence by using appropriate (accurate and selective) and sufficient scientific principles.</p>	<p>Appropriate and Sufficient Reasoning</p> <p>Reasoning uses scientific principles that are appropriate* and ALL evidence is linked to the claim. Reasoning is sufficient and easy to follow</p>	<p>Appropriate Reasoning</p> <p>Reasoning uses scientific principles that are appropriate* and MOST evidence is linked to the claim. Reasoning may be sufficient and is fairly easy to follow</p>	<p>Relevant Reasoning</p> <p>Reasoning uses scientific principles that are accurate but only somewhat relevant* and SOME evidence is linked to the claim. Reasoning may be sufficient and demonstrates some clarity</p>	<p>Inadequate Reasoning</p> <p>Reasoning uses scientific principles that are accurate or somewhat relevant, but not both* And reasoning loosely links evidence to the claim Reasoning is not sufficient and demonstrates some clarity</p>
<p>COUNTERCLAIM</p> <p>Develop counterclaims fairly, supplying data and evidence while pointing out the strengths and limitations of both claim(s) and counterclaims in a manner that anticipates the audience's knowledge level and concerns.</p>	<p>Compelling Counterclaim</p> <p>The counterclaim is clear and directly related. Evidence is appropriate* and sufficient. ALL evidence is linked to the counterclaim. The audience's knowledge level and concerns are taken into account.</p>	<p>Credible Counterclaim</p> <p>The counterclaim is clear and closely related. Evidence is appropriate* and may be sufficient. MOST evidence is linked to the counterclaim.</p>	<p>Weak Counterclaim</p> <p>The counterclaim is implied but not clearly stated.. Evidence is accurate but only somewhat relevant* and may be sufficient. . SOME evidence is linked to the counterclaim.</p>	<p>Inadequate Counterclaim</p> <p>An attempt at a counterclaim is made, but is minimally accurate.. Evidence is either accurate or somewhat relevant, but not both* and is not sufficient Reasoning loosely links evidence to the counterclaim.</p>

*Appropriate means it is accurate and most relevant: Accurate - in relation to content, Most relevant - using the most related data to support the claim or counterclaim

APPENDIX E
JOURNAL PROMPTS

Students were given the journal prompts at the beginning of class and expected to answer the prompt by the end of class or complete the prompt for homework.

Day 2: In your own words explain the C-E-R framework

D3 : What is the muddiest point about CER?

D4: Draw a labeled diagram of an atom.

D5: Use a Venn Diagram to compare atoms and elements.

D6: CER: Bobby claims that ice is a mineral. Use the CER framework to explain whether or not you agree with him. Underline claim, number evidence, bracket reasoning.

D8: Pick one mineral you identified from the Common Uses of Rocks and Minerals lab. Use the CER framework to show your thinking behind how you identified that mineral. Underline claim, number evidence, bracket reasoning.

D9: CER - Which mine is the most profitable? Underline claim, number evidence, bracket reasoning.

D11: Give two reasons you think phytomining would be better for the environment. Do you think changing environmental regulations (How companies impact the environment) should always be profitable (beneficial) to the company? Why or why not?

D12: CER - Which scientist deserves the grant for their phytomining presentation? Underline claim, number evidence, bracket reasoning.

D13: Fictional short story about how the rocks around us were made.

D14: Explain the rock cycle to a 6th grader.

D15: CER - Question: Did all rocks have to be igneous at one time?

D16: CER - Claim: The Navajo Sandstone in Utah is made of sediments that were once part of the Appalachian Mountains.

D17: CER: Claim: Metamorphic rocks come from the other two types of rocks.

D20: Thinking about the properties of water stations what are three questions you could investigate related to how water shapes Earth's surface.

D21: Propose a theory for weathering in one situation you observed.

D22: I now understand..... (based on weathering research)

D23: Summarize weathering investigation plan in paragraph form

D25: Reflect on whether or not the data you collected answered your initial question. Begin by restating your question.

D26: How does using evidence in argument writing help support your claim?

D27: How does using reasoning in argument writing help support your claim?

D28: Do you think you made a good “argument” with your weathering lab report? In other words, do you think people would believe your argument? Why or why not?

APPENDIX F
JOURNAL EXPECTATIONS & RUBRIC

Your science notebook will be used everyday to help you document your work, make sense of it, and give you a resource to revisit and apply your knowledge and insights in new learning situations.

Along with your notes and assignments, your journal entries will be completed by the end of each class. If a prompt is given, the entry should address the prompt. If no prompt is given, choose a piece of evidence from the list that will demonstrate you trying to make sense of the lesson.

Essential features include:

- Materials are organized
- There is a *Table of Contents*
- All entries are dated and titled/labeled
- If a prompt is given, the prompt is rewritten at the top of the entry.
- **There are three main assessment criteria for journal entries:** The ***Quality Criteria*** involve student-generated entries for ***making sense*** of each lesson (see chart). The two ***Structural Criteria*** involve the notebook's ***organization*** and ***completeness***.

<p>Making-sense of a lesson: Evidence that the student is developing scientific understandings</p>
<p>Evidence of student "sense-making" should be seen in the notebook, each day and "in their own words" and /or "of their own design"</p> <p>Statement of what is learned What I think... Quick writes I am surprised... I wonder... I now understand.... I rediscovered.... The important thing about.... Additional questions that remain or can be investigated Concept Maps Outcome sentences Venn diagrams Metaphors and analogies Plan of work Models Experimental design developed by students Claims and supporting evidence Summaries/conclusions Cartoons/pictographs/flow charts</p>

	Notebook Component	Assessment Criteria	Score	Comments
Quality Criteria	<p>Making Sense</p> <p>0 to 50 points</p>	<p>Work shows a clear difference between student observations and student ideas/speculations about what is observed</p> <p>Entries show in-depth processing of information. Science vocabulary is used correctly.</p> <p>Statements are supported by evidence.</p> <p>Explanation/reflection is in student's own words, diagrams, pictures, graphs.</p>		
Structural Criteria	<p>Organization & Structure</p> <p>0 to 20 points</p>	<p>Table of Contents is up to date.</p> <p>Materials/entries are organized appropriately.</p> <p>Notes are written chronologically</p> <p>Each entry begins with a date.</p> <p>Entries are labeled/titled.</p> <p>Handwriting is easy to read.</p> <p>Information/materials are organized such that they can be used as a resource.</p>		
	<p>Completeness</p> <p>0 to 30 points</p>	<p>Entries are found for each class. Entries are in complete sentences.</p>		

APPENDIX G
INTERVIEW QUESTIONS

Questions were taken from these options.

1. Do you like science?
2. Do you like this science class?
3. Are there certain times when science seems more relevant/connected to the rest of your life?
 - a. What are those times?
4. What is the purpose behind the Claim Evidence Reasoning framework?
5. What was the most difficult part about using the CER framework?
 - a. Why do you think that was?
6. What was the most useful part about using the CER framework?
 - a. Why do you think that was?
7. Can you walk me through how you tied your evidence to your claim?
8. Do you think using the CER framework helped you make sense of the material? Why or why not?
9. Did using the CER framework increase your interest in the subject matter?
10. How do you feel about your ability to write a conclusion?
11. Is there anything else you would like to share?