USING CLAIM, EVIDENCE, AND REASONING TO IMPROVE UNDERSTANDING AND CONCEPT RETENTION IN MIDDLE SCHOOL SCIENCE

by

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of the requirements for the degree

of

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in

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DEDICATION

This paper is dedicated to my late husband who always pushed me to be the best I could be. Thank you and I will love you always Michael.

ACKNOWLEDGEMENTS

Keith Miller for allowing me to experiment on my students.

Kathy Foley and Karen Alley for all of their help and expertise.

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ABSTRACT

Student retention of concepts over the long term has always been a struggle for teachers. This study attempted to use the Claim-Evidence-Reasoning (CER) method of teaching to improve students' retention of concepts taught at the start of the school year to the end of the school year and beyond. Using my three classes of 8th grade students, I attempted to get them to remember and use the concept of density throughout the year in several different applications and concepts. I used one class as a baseline or control for the study. This class was not explicitly taught to use CER in their experiments and labs involving density during the year. The other two classes were explicitly taught to use CER, had a worksheet to use to improve their analysis and reasoning skills on these same experiments and labs. The results of this study showed that the students who used CER in their experiments and labs retained and understood the information about density better than the students who were not exposed to CER. The students who used CER understood the concept of density more thoroughly and were able to use the concept in more of a real-world application way during their experiments and labs. They showed their knowledge with pre and post surveys in September and May and the students exposed to CER scored at least 20% higher than their counterparts that were not exposed to CER. This study showed that CER can be a powerful tool for students and can improve their retention of difficult to understand concepts over the course of a school year.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Context of the Study

Butte, Montana is known as the richest hill on Earth. There was enough copper mined out of the surrounding mountains here to pave a four-lane highway, both directions, for almost 400 miles. One hundred years ago, Butte was the place to be, and celebrities, presidents, and immigrants all came to Butte to work in the mines. Then the booming mining town with a population of 100,000 went bust, the mines closed, and Butte changed from the place to be to the place to avoid. This place to avoid now has a population that hovers around 33,000.

Butte is now part of the largest Superfund site in the United States. There is still one operational mine, but unemployment is still high compared to the rest of the state and country. The most recent unemployment rate is 4.7% compared to 3.2% for the rest of the state. This reliance on mining for good jobs has created an income disparity in the neighborhoods of Butte. There are more affluent neighborhoods and neighborhoods with less income. The median income for all of Butte is $49, 659. This is considerably lower than the national median income of $67,521. This difference can be seen and felt throughout the town. The professionals in town live in more affluent neighborhoods and the people who rely on more blue-collar or service industry type of positions live in less affluent neighborhoods. This creates a disparity in the neighborhood elementary schools.

The poverty rate in Butte is very high. The poverty rate is 16% compared to a national poverty rate of 13.4% according to the latest census information. There is a definite disparity of skills, background, and knowledge amongst students who come from certain elementary schools in the district. This trend reflects the national trends of the poorer neighborhood students having fewer academic skills and needing more remediation to achieve grade level skills. The students who live in the richer neighborhoods generally have better academic skills and need less remediation. Most of the time the students from the richer parts of town do not really mingle with the other students in a social setting and even getting students from different parts of town to work together on projects is sometimes a trial in the classroom.

Science and social studies classes are generally the only classes where these students from different parts of town have a chance to mingle and interact in an academic setting. This is impactful in one major way. These students are usually on the same level when it comes to their skills in the science classroom. This is because our district tends to gloss over science education in the elementary schools and it is not really a priority. So, whether the students come from the affluent Hillcrest neighborhood, or the poorer Kennedy neighborhood, they all have underdeveloped skills when it comes to actually doing science.

This brings to me to the impact of my study. The influence this district policy had on my teacher training was immense. I was going to college at the same time my own children were going through elementary school. I saw firsthand how a worksheet about bats was considered their science education for the week. Or my personal favorite elementary science lesson, a movie, “Osmosis Jones” was considered science education. I became convinced that the science education in my district needed to be improved!

Our middle school here in Butte has a student population of 636 students in the 7^{th} and 8^{th} grade. The students are broken up into five teams of five core subject teachers. These core subjects are math, reading, English, social studies, and science. The thought is that the students on the team would all have the same five teachers, and those five teachers would be keeping a watchful eye on their team of students and intervene when necessary. Over 75% of our student body qualifies for free or reduced lunch, which speaks to the poverty rate in Butte.

We do have several Title 1 interventions for reading, English and math, but no such interventions exist for science and social studies. There are also special education classes for reading, English, and math, but not for science or social studies. In a typical classroom of my science students, I have students who are in advanced classes and students who have the reading and math skills of an elementary student.

I learned everything I could about inquiry science and how to perform experiments in the classroom. I wanted the children of Butte to experience science first-hand. And I wanted it to be more impactful than a worksheet or a movie. I want my students to actually understand and remember hard to know science concepts. I want them to be able to think critically about the world around them and help to make the world a better place. This leads me to the questions for this study.

Focus Question

My focus question was, “How does the use of Claim-Evidence-Reasoning influence academic achievement and application of skills and knowledge?”

My sub-questions include the following:

1. How does the use of Claim-Evidence-Reasoning influence academic achievement?
2. How does the use of Claim-Evidence-Reasoning influence application of skills and knowledge?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Science education is a complicated and multi-faceted process. During this exploration, I will be focusing on the ideas of using inquiry to excite and engage students. I will also discuss alternative assessments for science students. Then I will be discussing using the Next Generation Science Standards as a baseline for everything I do in my classroom. And most importantly, I will use Claim-Evidence-and Reasoning (CER) to connect all of these to student learning.

Using Inquiry

Using inquiry teaching methods in science is something that has been studied and researched to show that there are significant learning gains to be achieved by this type of instruction. Inquiry based learning is an approach to instruction that begins with a question. If we, as teachers, can engage a student's curiosity we can intrinsically motivate them to learn Singer (2017).

As a teacher, I firmly believe that using this approach to learning helps students see and understand science in a way that cannot fully be duplicated by traditional teaching methods Wilson et al. (2010). This study used various groups of secondary students and segregated them into different groups and subgroups. These groups received different types of instruction. The student groups with the highest achievement in science were the students who received inquiry style instruction. This applied to the different subgroups as well. The gender-based groups and race-based groups also showed significant gains in their learning as opposed to the more traditional based groups.

Furthermore, inquiry-based learning promotes three skills among middle school students. Greater interest in the subject, greater self-efficacy for students in STEM (Science, Technology, Engineering, and Mathematics) subjects, and students reported more utility in science and mathematics (Riegle-Crumb et al., 2019). These are all desirable skills that science teachers often try to instill in their students and often struggle with teaching these skills. Making science meaningful and relevant to students and their lives is also a way to promote student understanding and success (Gormally et al., 2009).

One other aspect of student learning is motivation to answer their own questions for students. When using an inquiry learning style students are in driven by their own need to answer questions about the world around them (Baker et al., 2008). Bybee (2013) says that the student wants to learn more when they are trying to answer questions that they develop themselves. This is an important part of using inquiry learning to teach science. Science is all about answering questions about the world and how it works.

Next Generation Science Standards

The Next Generation Science Standards (NGSS) were developed to increase student understanding of science and revolutionize the way science is taught to school children. The NGSS take inquiry learning to a whole new level of understanding for the teacher and the students. The notion of science learning was reformed with the development and implementation of the NGSS (Bybee, 2013).

The Next Generation Science Standards were released in 2013. Montana adopted their version of NGSS in 2016. This adoption has led to a flurry of training and curriculum development without any real thought into how to implement these standards and teach our students to be scientists.

The hardest part of implementing these standards is the idea of how to make our lessons three dimensional to align with NGSS (William et al., 2008). Lessons and units aligned to the standards should be three-dimensional; that is, they should allow students to actively engage with the practices with big questions and apply the crosscutting concepts to deepen their understanding of core ideas across science disciplines. The implementation of these standards and this three-dimensional thinking is going to require some shifts in teaching practices to fully utilize all of NGSS.

There are four high impact shifts in teaching practices to deepen the impact of NGSS for our students (Duncan & Cavera, 2015). These shifts will help students learn and teachers to teach science in a more meaningful and impactful manner. The first shift is to intentionally build opportunities into our curriculum for students to engage in Science Practices around central phenomena chosen to evoke curiosity in and provide context for our learners. This shift will allow students to have greater autonomy compared to students taught in a more traditional method. This shift utilizes inquiry learning in a more meaningful manner.

The second shift is the usage of an anchoring phenomenon. Many science teachers choose to teach science because we love science. Learning and practicing science may not challenge us the way it does many of our students (Duncan & Cavera, 2015). The biases of our own understanding may cause us to assume our students see the same relevance and interconnections we now take for granted. This is why we center each unit of study around an anchoring phenomenon (Penuel et al., 2015). This ignites our students' curiosity and can actually excite them about learning. While a phenomenon may be complex in terms of the fundamental laws that explain it, the actual events we present our students are often quite simple.

The third shift requires a change in assessment. Our challenge is to design assessments that require students to engage in those Practices to demonstrate how well they understand “Disciplinary Core Ideas,”, which NGSS defines as, “The fundamental ideas that are necessary for understanding a given science discipline.” (Penuel et al., 2015) The traditional paper and pencil tests that veteran teachers are very adept at creating and assessing content do not necessarily assess the practices.

The fourth shift needed for high impact implementation of the Next Generation Science Standards is the usage of the cross-cutting concepts. Crosscutting concepts have application across all domains of science. As such, they are a way of linking the different domains of science. They include patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and stability and change. The Framework emphasizes that these concepts need to be made explicit for students because they provide an organizational schema for interrelating knowledge from various science fields into a coherent and scientifically based view of the world (Wolf et al., 2008). The consistent and explicit use of these concepts and all of these shifts in teaching can lead to high impact usage of the Next Generation Science Standards.

These shifts will all allow for our students to have a deeper understanding of science and how the process of science actually works. As teaching become more complex with how our students approach their learning with inquiry and NGSS, teachers are going to approach assessing students in a new way as well. Banko et al., (2013)

Assessment

Students are often being asked to write their thoughts when they are working in an inquiry science lab situation and using NGSS often requires writing skills. This often is a barrier for students who do not have great writing skills (Banko et al., 2013). There are several ways to improve student writing and teachers' assessment of their students' writing skills in the science classroom. The use of formative assessments and feedback to students are necessary components of assessing student understanding of their inquiry learning and the NGSS (Ruiz-Primo and Li 2013).

Assessing students understanding of complex materials is often difficult. Add into that the inability of educators to see into their students' minds and seeing how students' reason is especially difficult. Gotwals and Songers (2006) suggest a method for doing exactly this. They suggest using formative assessments to assess student understanding during the concept teaching instead of only utilizing a summative assessment at the end of the teaching unit. Formative assessments provide insight into how students are doing in the moment, but not necessarily if they understand the big picture. Something more robust is needed to fully assess student understanding.

Feedback is an important part of the assessment process. Feedback must be informative and not just numbers and symbols to truly be effective at improving student learning. Many teachers do use the number and symbol method of feedback, and this can leave the students confused about their own learning (Maria Araceli Ruiz-Primo & Min Li, 2013). Feedback must be constructive in nature and be able to be understood by the student. It should provide clarification for the students so they can recognize their mistakes and learn from them Harrison (2015).

Most of the push for assessment in the classroom has changed from the formal summative assessment at the end of the chapter type of assessment to a more relaxed, informative approach. The need for continuous feedback for the students has changed assessment in the classroom to more of a formative assessment type of procedure. (Gallant, 2008) This change has come about because of the need to improve students' academic performance.

This change has also brought about a need for assessing student writing in the moment as they complete it. Normally, assessing student writing takes a long time for teachers and is a complicated process. This process can be streamlined by the use of Claim-Evidence-Reasoning (CER) and the use of a CER template.

Claim-Evidence-and Reasoning

Claim-Evidence-Reasoning is an analytical way of thinking and an argumentative style of writing that develops student skills in these two areas. One of the hardest things to assess is students' thinking during data analysis and higher order thinking questions on assessments or during other exercises in the classroom. A different approach to student thinking is required for students to be able to think clearly, express their thoughts in writing, and for the teacher to be able to assess their understanding of their thinking. (Gallant) This brings the topic of focus to using Claim-Evidence-and Reasoning (CER) in the science classroom.

Students struggle with higher order thinking and the use of an anchor to help them solidify their thoughts can help calm their anxiety when they are asked to process things at a higher level. Kennedy and Folkes (2018) suggest that using a template or an anchor to help students organize their thoughts before they start writing can help with this anxiety and can improve student thought organization when they do write their thoughts down. When students write their thoughts down thoroughly and consistently, they develop a deeper understanding of concepts. This deeper understanding of concepts leads them to relating these concepts to real world applications and more relevance to their lives.

One of the drawbacks to using inquiry learning, formative assessments, and the three-dimensional aspects of NGSS is the more abstract aspects of science. Things like the merit of the study, the analysis of data, and the reasoning behind the data is a struggle for middle school scientists (Wilson et al., 2010). Middle school students tend to understand the need for samples, controls, and organizing data collection. They do not often think about the merit of their investigations, and the drawing of conclusions from their systematic collection of data (Joseph Krajcik et al., 1998). Teacher involvement and structure of questioning is needed for students to understand more cohesively what is happening in the classroom. Using Claim-Evidence-and Reasoning would help with this need for concrete data collection. Students enjoy inquiry learning and it helps to promote a positive classroom environment. There is more student teamwork, more cohesiveness, and a positive classroom environment when there is inquiry learning in a science classroom (Wolf et al., 2008). Learning environment and achievement are often correlated.

Teaching using CER requires a planned approach when completing assessments. Brownen (1999) found that the need for planned formative assessments was integral to students' learning. Planned formative assessments are those that are completed with the whole class and used to drive learning. Quick, unplanned formative assessments that take place in small groups or one on one interactions can help clear up student misconceptions. However, the planned formative assessments are what should be used when planning learning.

By using inquiry science lessons, formative assessments, and the NGSS approach to teaching a science classroom teacher can increase a student's understanding of science and the world around them. By using CER, this research project will attempt to see if the students can improve this understanding even more.

CHAPTER THREE

METHODOLOGY

The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for work with human subjects was maintained (Appendix A).

The CER (Claim Evidence and Reasoning) method of teaching science is a complicated but rewarding process for students. The process is important when teaching all three dimensions of the Next Generation Science Standards. This study is attempting to see if the thoughtful and specific usage of CER will improve students' skills and knowledge during the school year. The purpose and focus of this study will be focusing on the concept of density and its usage throughout physical and earth science concepts throughout the school year. The focus question of this study is, How does the usage of Claim-Evidence-Reasoning influence academic achievement and application of skills and knowledge?

Demographics

I have been teaching for fourteen years. Eleven of those years have been at the middle school where I am currently teaching. I teach 7th grade life science and 8th grade physical science to approximately 120 students every year. These students have varying reading, math, and language skills. I teach students who can barely add whole numbers together and I have students who are taking geometry up at the high school. This makes for an interesting classroom dynamic and a broad range of background knowledge among my students.

East Middle School is the only public middle school in Butte, MT. The six elementary schools in the district feed its student population. It has over 600 students who are split onto five different teams of students. Each team of 120 students, theoretically, have the same five core teachers. The core classes are reading, math, English, social studies, and science. If a student is struggling in reading, math, or English, there are Title 1 classes available for help for those students. Social studies and science are the only classes that truly mix and have all 120 students.

The student population of East Middle School is 95% white or Caucasian. The other 5% is a mix of 3% Native students, 1% African American and 1% Asian American students. This student population is a microcosm of the city population. Montana is not really an ethnically diverse state and sometimes that lack of diversity shows.

The only real minority group in our school is the students who qualify for free and reduced lunches. Over 65% of our student qualify for this lunch program. This creates a disparity in the student population that is evident in my students' social and academic interactions.

East Middle School's curriculum is written so that three years of middle school standards are attempted in two years of middle school science. The middle school is only 7th and 8th grade. The 6th grade teacher tries to tackle some of the Earth science standards, but they do not take enough to make a difference. The teachers at East do try to do our best, but sometimes know that the topics are not covered in depth enough. The teachers do try to perform hands on projects, engineering design challenges, and experiments, and incorporate all three dimensions of the NGSS.

Treatment

This study will be utilizing three of classes of eighth graders in this study. These classes are similar in their populations of students. There are IEP and 504 students in every class. There are also a similar number of higher achieving students and students who are in Title One classes for math and reading.

All three classes will be given a pre and post survey. The students will be given the pre survey in September as a way to understand what they know about the concept of density before learning about it. The post survey will not be given until May to gauge student understanding of density throughout the school year. All three of the classes will be completing the same labs, activities, and lessons as each other. The only change that is being made is the way that lab activities are being analyzed by the students.

One class will used as a baseline or control for the study. This class will not be specifically taught the CER method of evidence reasoning. They will be aware of the CER method, but it will not be explicitly taught to them. The CER method will not be reinforced but will be mentioned during labs and experiments throughout the school year.

The other two classes will be specifically taught the CER method and will be expected and reminded to use this method throughout the school year. These students will be using the student CER paper and rubric. (Appendix C). These students will be completing the CER method during every lab involving density throughout the school year. These students will also receive an example notes page about CER (Appendix D) that will be kept as a reference guide for them about using CER.

All three of the classes will be given a notes page about density (Appendix F) and will be completing a concept map about density in their lab notebooks. The notes page will be kept throughout the school year in their lab notebooks. The concept map (Appendix E) will be introduced after learning about density in September. This concept map will then be updated and checked throughout the school year as a way to gauge student understanding of density during the year.

These concept maps will be used as formative assessments during the actual unit lessons to monitor student learning during this time. The students will work on concept maps and other assessment monitoring strategies to monitor their understanding of the science concepts of density and how it relates to current topics of learning.

This study will be using the district data on students that is collected at the start of the school year and in February. This data is MAPS (Measure Academic Progress) testing data.

This data should give an accurate picture of the understanding level of the students in the three classrooms. This data will provide a basis of science concept understanding throughout the school year and determine if the students made any significant academic achievement gains.

This study will be utilizing the digital resources of my school district for data collection and analysis. This study will also be utilizing Microsoft Teams as a platform for delivery of the surveys. During the course of the study, pre and post surveys (Appendix D) will be given to the students about their learning. These surveys will be conducted electronically and anonymously through Microsoft Teams. This will allow for student freedom in their answers and hopefully some honest feedback. Microsoft Excel will be used as a data analysis tool and graph generator.

This study will also use an interview process to determine how the usage of CER helped the students' learning from their perspective. The interviews will be conducted during an advisor period that is in the school schedule every day. There are students from all three science classes in this advisor period. They are a random subset of the students in the three science classes. These are the students that will be interviewed to determine what they thought of their learning during the school year.

Data Collection and Analysis Strategies

Question: How does the use of Claim-Evidence-Reasoning influence academic achievement and application of skills and knowledge?

Statement/Observation: Due to the nature of our curriculum, I am not really able to assess students on topics from the fall semester of the school year. I have observed them not remembering main ideas and topics from that time period when situations arise later on in the school year. I wonder how much of the science knowledge that I have tried to teach them through projects and experiments is actually in their long-term memory.

In order to study this question, I will be using our district NWEA MAPS data as an indicator for how much science content knowledge the students have and how much they gain or lose throughout the school year. I will also be using the pre and post surveys (Appendix B) to determine exactly what the students understand about the concept of density throughout the school year.

I will be using interviews to determine what the students thought of their learning throughout the school year and if they thought the usage of CER helped them with their learning and thinking.

Sub Question: How does the use of Claim-Evidence-Reasoning influence academic achievement?

To collect data on this topic, this study will be attempting to teach students how to use the Claim-Evidence-Reasoning method of writing up their science labs and experiments. Studies have shown, that if students have to explain themselves using a written format, their retention might become better, and they may actually remember concepts like density from October to May.

During the course of this study, two 8th grade classes will be explicitly taught to use Claim-Evidence-Reasoning (CER) as part of unit on how to actually do science that is taught at the start of the school year. During the school year, these students will be using the CER method during various lesson, experiments, and labs. The students will be familiar with the process and how to connect their claim to evidence and then reason how the two things go together.

Sub Question: How does the use of Claim-Evidence-Reasoning influence student application of skills and knowledge?

This study is planning on using several data collection methods for my capstone project. This study will be using field observations, surveys of students, both before and after the data collection period, samples of student work, and formative assessment information gathered during class time.

The two data collection methods that the study will be focusing on for this part of the research will be student surveys and formative assessments. These two methods will provide a detailed glimpse into how the students' minds are working. The formative assessment will be an objective way to gauge student understanding of concepts. Most of these techniques are quick, easy, and provide me with information about how the students are understanding the concepts of the day.

The other data collection method will be student surveys. At the start of the school year all the students will be given a survey about their understanding of the long-term density concepts. Then at the end of the school year, all the students will be given the same survey and see if the understanding of the material improved. This will give the study a look into the students' understanding in more of a long-term concept retention. This survey will be given anonymously with random question and answer orders. The survey will be given over Microsoft forms and teams.

The formative assessment technique that the study will be using for data collection on this question is having the students develop a concept map or graphic organizer to help them with their thinking. As the teacher, I will be providing them with a few of the main vocabulary words and they will have to develop a map on how those words are connected to each other. The method that they use for connection will be up to them, but the grading will expect to see specific words linked together. This will allow the study to judge how well the students understand the concepts of the words and how the words relate to each other.

When it comes to data collection for the concept map, the study will be scoring the students based on their word pairs that they connect in the concept map. A number will be given them based on how many word pairs or groups they get correct. This will show how many students grouped the words together correctly and allow for some flexibility for the analysis of the data. Using the survey data, class averages will be calculated and compared to classes that did not focus on the CER concept as hard.

These methods are outlined in the table below as a guide for how this study will be conducted. The survey, NWEA Maps Data, and the student notebooks will provide the evidence to determine if using the CER method of teaching will help with student concept retention and knowledge.

Table 1: Research Matrix

	Data Collection Instruments		
Research Q: How does the use of Claim-Evidence-Reasoning influence academic achievement and application of skills and knowledge?	Pre-Unit Survey	Post Unit Survey	Interview
Research SQ. 1: How does the use of Claim-Evidence-Reasoning influence academic achievement?	Concept Maps	Student CER Paper/Student Notebooks	District MAPS data
Research SQ 2: How does the use of Claim-Evidence-Reasoning influence student application of skills and knowledge?	Student Notebooks/Concept Map	District MAPS data	Survey

CHAPTER FOUR

DATA ANALYSIS

Results

The data indicates that the students that were explicitly taught to use CER (Claim, Evidence, Reasoning) during the school year remembered the concept of density better than students who were not explicitly taught to use CER.

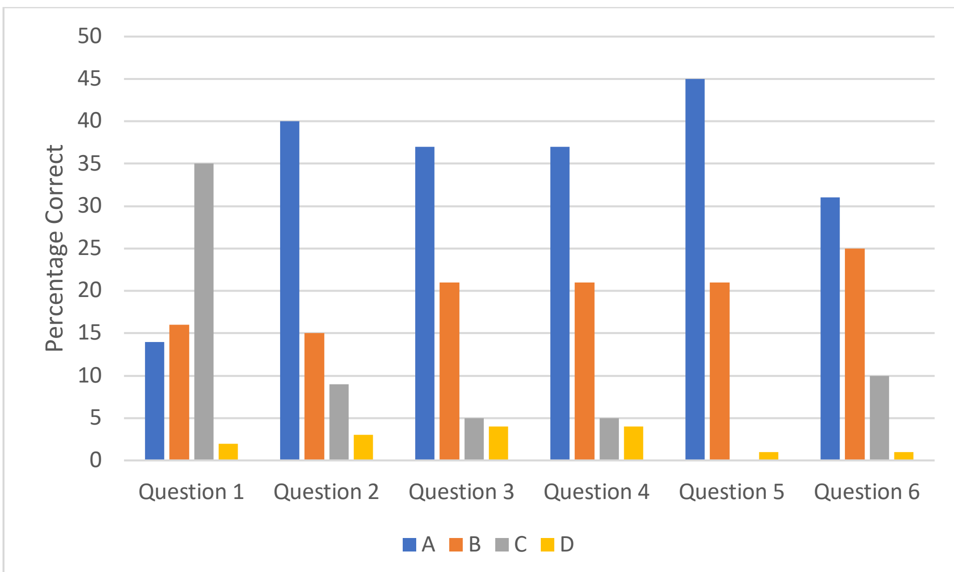

Figure 1: Pre-Treatment Survey Responses from September: The distribution of student answers from the anonymous survey given to all students in September (*N*=67).

The data from the survey (Appendix B) given at the start of the school year indicates that there is a good understanding of the basics of density, but some confusion on the details with most of the students. The correct answer for these questions is answer A. As is indicated in the graph, less than half of the students understand the basics of density pretreatment.

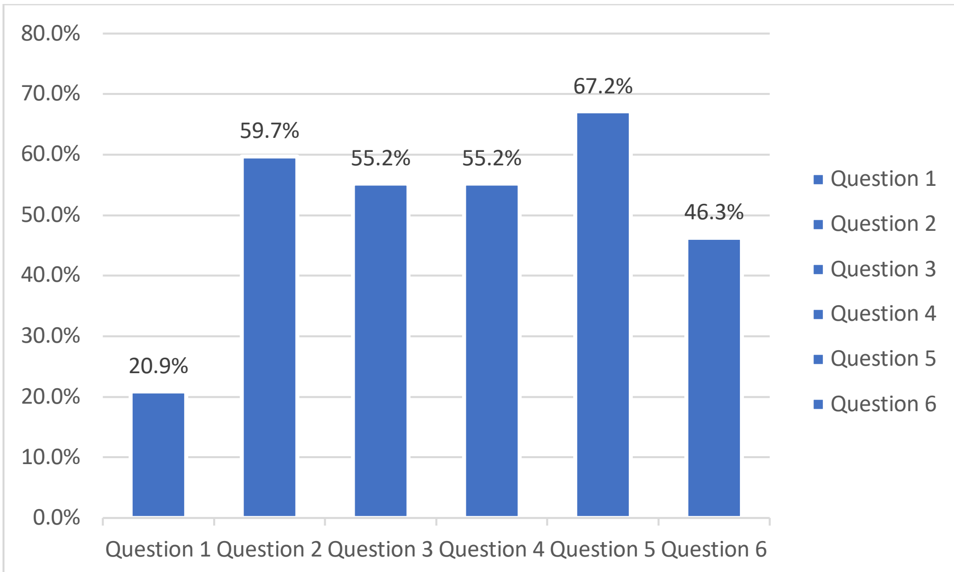

Figure 2: Percentage of students with correct answers in September (*N*=67)

Figure 2 shows the distribution of correct answers from each of the six survey (Appendix B) questions. As indicated by the students' answers, the question that most students missed was the first question. This question was about whether density is a physical or chemical property of matter. The students did the best on question five from that same survey at the start of the school year in September before any explicit instruction was given in either CER or density. Question five was asking about how to find the density of an object.

The table below (Table 2) shows the student NWEA MAPS testing data.

MAPS Test Date	Students at or above grade level in science concepts in the non-treatment group	Students at or above grade level in science concepts treatment group
Fall 2021	9	16
Winter 2022	15	31

Table 2: NWEA MAPS Data of Students who are at or above grade level understanding. (*N*=67)

This MAPS data was generated using NWEA information and testing website. All 67 8th grade students were administered this test both times. There were significant gains made from September to February in understanding general 8th grade science concepts by all of the students. This would indicate that the students are understanding science concepts more adequately as based on standardized testing norms. (Table 2)

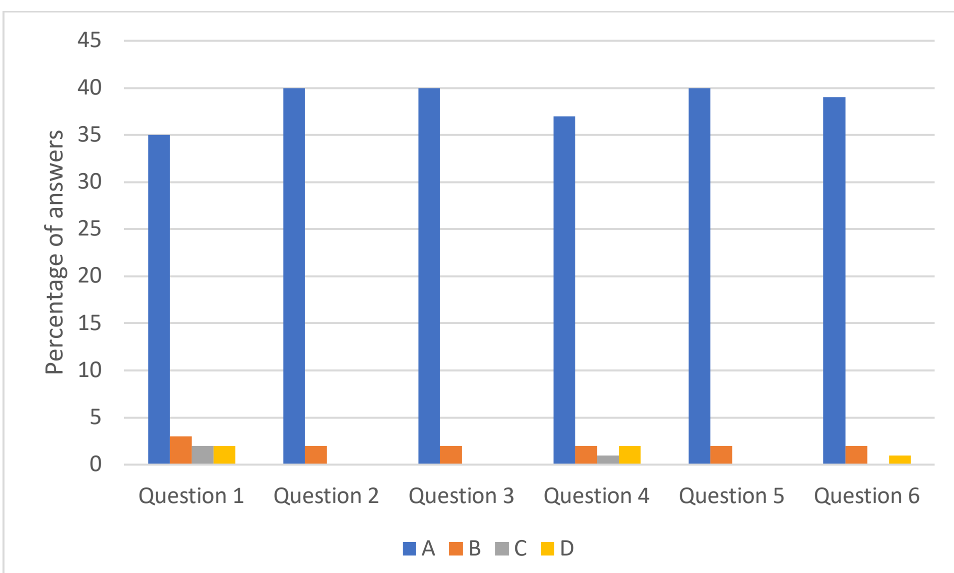

Figure 3: Survey responses in May for students who used CER (*n*=42)

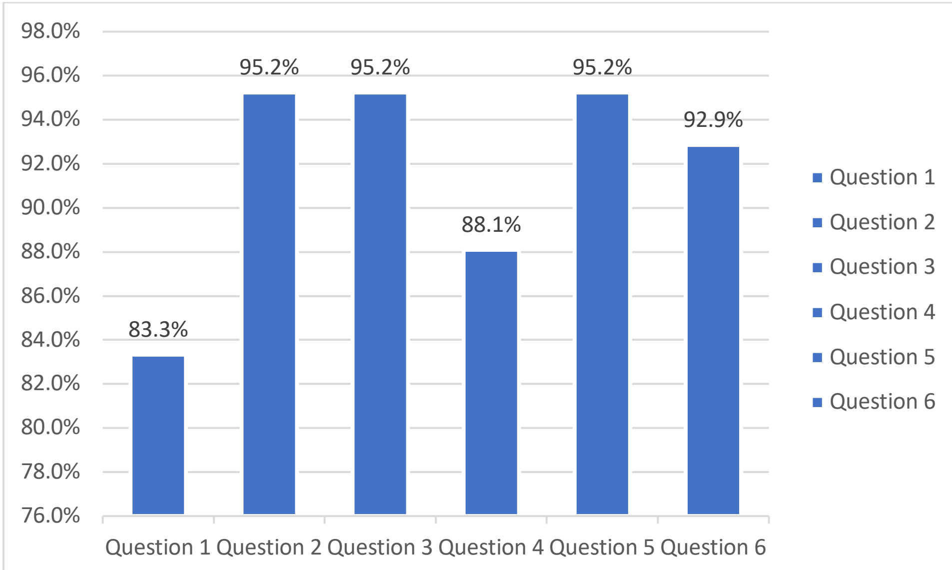

Figure 4: Percentage of students with CER with correct answers to survey in May *(n*=42)

Figure 3 and Figure 4 describe the distribution of students with correct answers to the survey (Appendix B) questions in May at the end of the school year. These figures are focusing on the two student classes that were given explicit CER instruction. As indicated by the data, the students were able to answer the survey questions in a more proficient manner. The only question that gave the most students trouble was still question 1, but over 80% of students were still able to answer this question accurately. The other five questions had an accurate answer rate over 88%. This would indicate a high understanding of density.

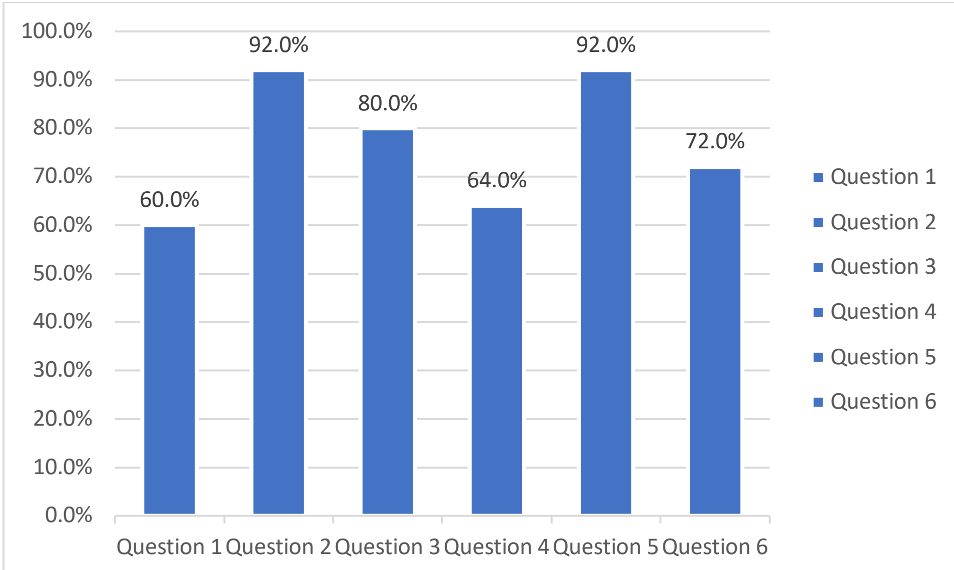

Figure 5: Percentage of students without CER with correct answers to survey in May *(n*=25)

Figure 5 shows the survey percentage data from the student group that was not explicitly taught using CER. These students were not as accurately able to answer the survey questions. Question one still had the lowest number of accurate answers, but the percentage with this student group was lower with an accuracy of 60%.

There was a greater range of accurate answers with 60% accuracy on question one being the lowest and a 92% accuracy on questions two and five. This could indicate that there is some understanding, but not a complete understanding of the concept of density.

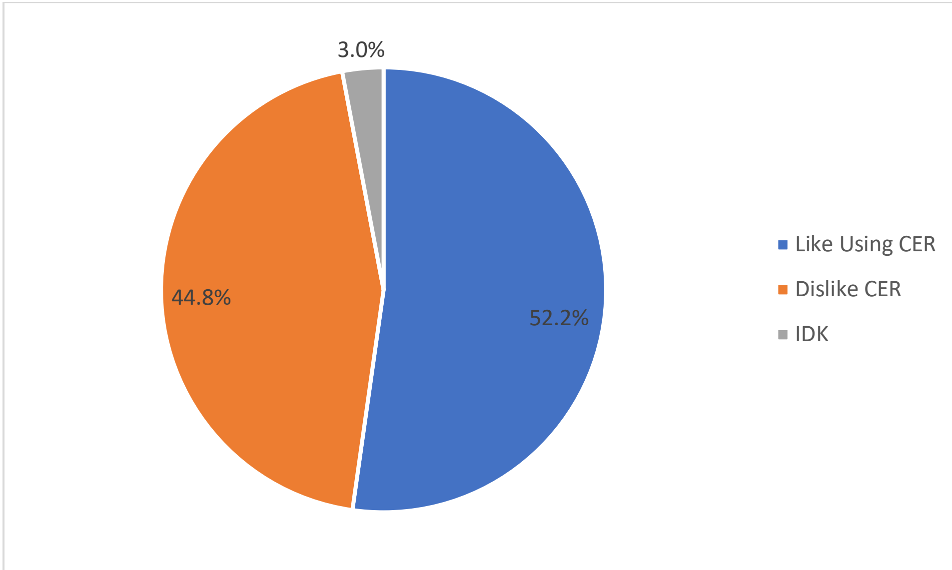

Figure 6: Interview Results (*n*=21)

Figure 6 shows the interview results from the two questions that I asked of every student I interviewed. I asked every student in my mixed advisory class, if they liked using CER at some point during their interview. The results were mixed in that 52% of students reported that they liked using CER, almost 45% did not like using CER and 3% of students reported that they did not know or would not give me a coherent answer about their likes and dislikes.

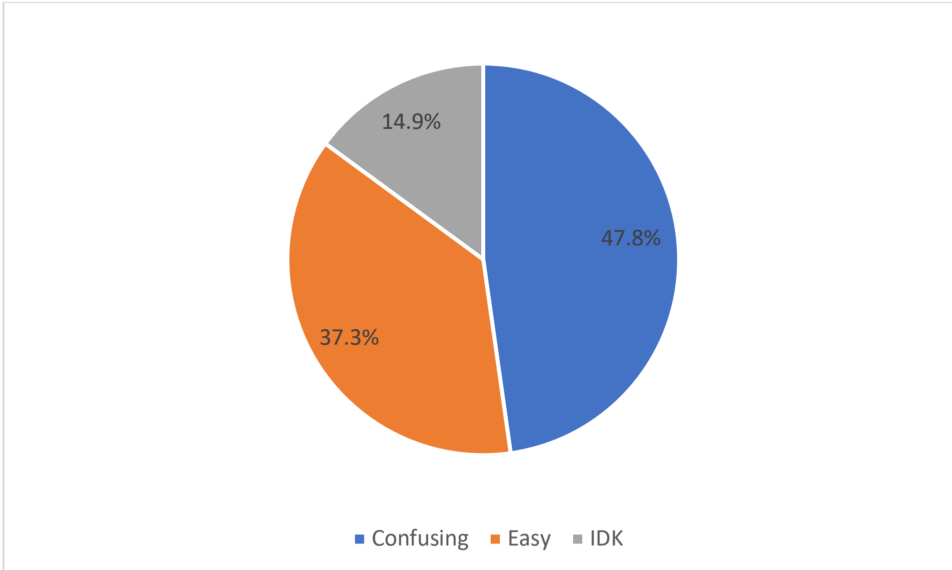

Figure 7: Interview Student Perception of CER (*n*=21)

Figure 7 shows the results from how students in my mixed advisory class, perceived CER in the science classroom. The results from this question were very mixed. Almost 48% of students found using CER confusing or hard to use. 37% of students reported that using CER was easy and made the analysis during labs easier on them to complete. Almost 15% of students did not know or could not give a coherent answer as to whether the usage of CER helped them in their science learning through the school year.

One piece of the study did not work out as intended. The concept map was meant to be a work in progress that the students kept in their lab notebooks and updated as we worked on density concepts throughout the school year. Almost 75% of my students lost their lab notebooks at some point during the school year. This resulted in the concept map data going missing or just not being complete enough for analysis. I believe that this was due to COVID and these students not having a normal school experience for the last two school years. They did not have adequate student skills to keep and maintain a notebook for an entire school year.

Therefore, the idea of a concept map that was kept and updated throughout the school year had to be discarded.

CHAPTER FIVE

CLAIM, EVIDENCE, AND REASONING

Claims from the Study

This study was undertaken with the purpose of trying to improve students' retention and usage of concepts that are taught at the beginning of the school year.

Claim One

The study found that students who were explicitly taught to use the CER (Claim, Evidence, Reasoning) method of data analysis in their labs and experiments remembered the concepts taught to them at the start of the school year better than students that were not explicitly taught the CER method.

The two classes that were explicitly taught the CER method demonstrated a greater knowledge of density in the post treatment survey. The questions were all answered with an 80% or higher accuracy in these two groups. This is a 20% increase over the non-treatment groups who only scored with a 60% or high accuracy. This indicates that the treatment of using CER worked for these students to help them remember the information taught about density at the start of the school year.

The concept of density appears throughout the school year in various topics taught. The students need to remember the basics of the concept of density and then apply the basics to more real-world applications of density. Just as (Banko et al., 2013) suggested that writing in science improves student skills. I believe that the usage of CER during this study to promote writing about the density labs and activities that were performed allowed the students to remember and utilize that knowledge throughout the school year. The writing reinforced concepts and allowed for a deeper understanding of the concepts that were taught during each activity.

Claim 2

The CER method allowed the students to increase their application of science knowledge.

The 42 students who used CER experienced gains in the NWEA MAPS scores and in their understanding of density and how it applies to their life. Over half of these students increased their knowledge and skills to at or over grade level. This is compared with a third of the students in the non-treatment groups that increased their MAPS score to grade level. This group did experience gains as well, just not as much as the treatment group. The students were able to increase their standing on the MAPS test due to their data analysis skills improving. The 25 students who were not using CER also experienced gains in their NWEA MAPS scores and in their responses to the survey but did not improve as much as the other students. These students also struggled with higher order thinking and did not make as many gains in their MAPS scores as the other students.

The students still leaned, but the students in the treatment group learned and understood more that the students in the non-treatment group. When students are engaged in a learning activity that has meaning to them and relevance to their life, they learn the material at a deeper level. (Reigle-Crumb et al., 2019). I believe that CER helped to make the activities and the concept of density more relevant to the treatment group. This allowed for deeper understanding and learning of the material. This in turn allowed for the improvement of MAPS scores at a higher rate in the treatment group versus the non-treatment group.

Claim 3

My students liked using the CER method and they were cognitive that CER helped them with their thinking.

My interview results of my 21 advisor students indicated that over half of them liked using CER. They indicated that using CER helped them to organize their thoughts when they were completing data analysis. This shows up in the student perception of CER where over 40% of students said that using CER was easy. There were some students who did not use CER in this subgroup, and they accounted for the most of the 45% who did not like CER and for the 37% of students who said that CER was confusing.

This is the same as the study performed by Kennedy and Folkes in 2018. In that study, the usage of a template to help organize student thinking reduced student anxiety about science and the students understood more of the material. I believe that using the CER template (Appendix C) allowed the students in the treatment groups to overcome their anxiety about the concepts being taught and allowed for student learning at a higher level than the non-treatment group. The students enjoyed the learning of the science concepts because they were less anxious about the learning due to the CER template.

Value of the Study and Considerations for Future Research

This study shows that middle school students can perform higher order thinking when explicitly taught how perform this type of thinking. Too often teachers expect rote memorization as thinking and that is just not true. By using the CER method, my students were able to understand and apply the basics of concepts in real-world ways and make the theory that I was teaching them apply to their lives. This would be interesting to expand to other teachers and even share at the district level to push CER style learning into the mainstream in my school district.

This research would be also interesting to continue on in other subjects, or even as an interdisciplinary unit with another department. The English teacher on my team of teachers was very excited about the work that the students were doing in her classroom and wanted to know more. I would love to collaborate with another class in this manner because middle school students are very concrete in their thinking that the skills, they learn in other classes necessarily cross over. I would like to shake up this belief and use the skills of the English teacher to improve my own writing teaching skills as well as they students' writing skills.

I would also like to expand the use of CER in my classroom. I think it would get overwhelming for students to use all of the time, but as we move throughout the school year, I would like to have to have students perform CER during key activities throughout the school year. I would also use CER as a summative assessment for projects throughout the school year as more of a formal lab report than just the lab notebooks.

The CER method is a powerful tool and should be highly utilized in the classroom setting.

Impact of the Action Research on the Author

This action research project has shown me that during the hustle and bustle of the school year, I need to be more mindful of teaching data analysis to my students. I know that using the

CER method with my students will help accomplish that goal. I would ultimately like to be able to not have to nag my students to use CER, but rather have them complete CER in more fluid manner. I would love to get to the point where we can drop the template and have the students complete this type of thinking on their own without much prompting. Of course, this will prove to be utopia, but still a wish of mine.

I also appreciated the insightfulness and honesty of my students as we worked through using CER together. Teaching is all about the relationships and I know that this project changed the relationships I had with my students for the better. The interview process allowed me to have a meaningful conversation with students one on one. I thoroughly enjoyed this, and relationships changed between myself and these students. They became very open and honest about school and what happens at school for them because they knew I would listen and not judge. I would like to have a way to continue this type of relationship with my students every year. I know that an interview at the beginning of the year would not accomplish this, but perhaps doing something towards the middle might work.

I really enjoyed the honest feedback and will be continuing something in this manner from now on.

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APPENDIX A

IRB APPROVAL LETTER

MSSE Research Projects Only
(6/16/14)

PLEASE TYPE YOUR RESPONSES. Applications can be emailed to irb@montana.edu. Submit application, along with any surveys, subject consent forms, and all other relevant materials. For information and/or assistance call 406-994-4706.

Please type responses in bold. Do not type in all capitals.

Delete above two text boxes of instructions (and this sentence) prior to submission and/or printing.

****

THIS AREA IS FOR INSTITUTIONAL REVIEW BOARD USE ONLY. DO NOT WRITE IN THIS AREA.
Confirmation Date: 12/20/21 Mark T. Quinn
Application Number:

****

DATE of SUBMISSION:

-Okay as exempt
-MSSE Classroom assessment
-Little/no risk
-Principal approved
-No concerns
MQ 12/20/21

Address each section – do not leave any section blank.

I. INVESTIGATOR:

Name: **Jennifer Nardiello**
Home or School Mailing Address: **1001 West Granite Street Butte, MT 59701**
Telephone Number: **(406) 422-8873**
E-Mail Address: **nardiellojc@bsd1.org**
DATE TRAINING COMPLETED: _3/4/2019____ *[Required training: CITI training; see website for link]*

Investigator Signature Jennifer Nardiello

APPENDIX B

SURVEY GIVEN TO STUDENTS

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

Question 1
Density is a:
1. physical property 2. Chemical property 3. Both 4. Neither

Question 2
Mass is measured in:
1. grams 2. Pounds 3. Ounces 4. Newtons

Question 3
Volume of a liquid is measured in:
1. liters 2. Cubic centimeters 3. Cups 4. Gallons

Question 4
Volume of a solid is measured in:
1. cubic centimeters 2. Liters 3. Gallons 4. Cups

Question 5
Density is calculated by dividing:
1. mass/volume 2. Volume/mass 3. Weight/Force 4. Force/Weight

Question 6
If Substance A is less dense than Substance B:
1. Substance A will float above Substance B 2. Substance B will float above Substance A
3. They will mix evenly 4. They will explode

APPENDIX C

CONCEPT MAP INSTRUCTIONS

Instructions: You can use words more than once. These words all connect to each other in some way. I want you to create a diagram that shows how these words are connected to each other.

Density

Mass

Volume

Grams

Cubic centimeters

Milliliters

Ratio

Space

Amount

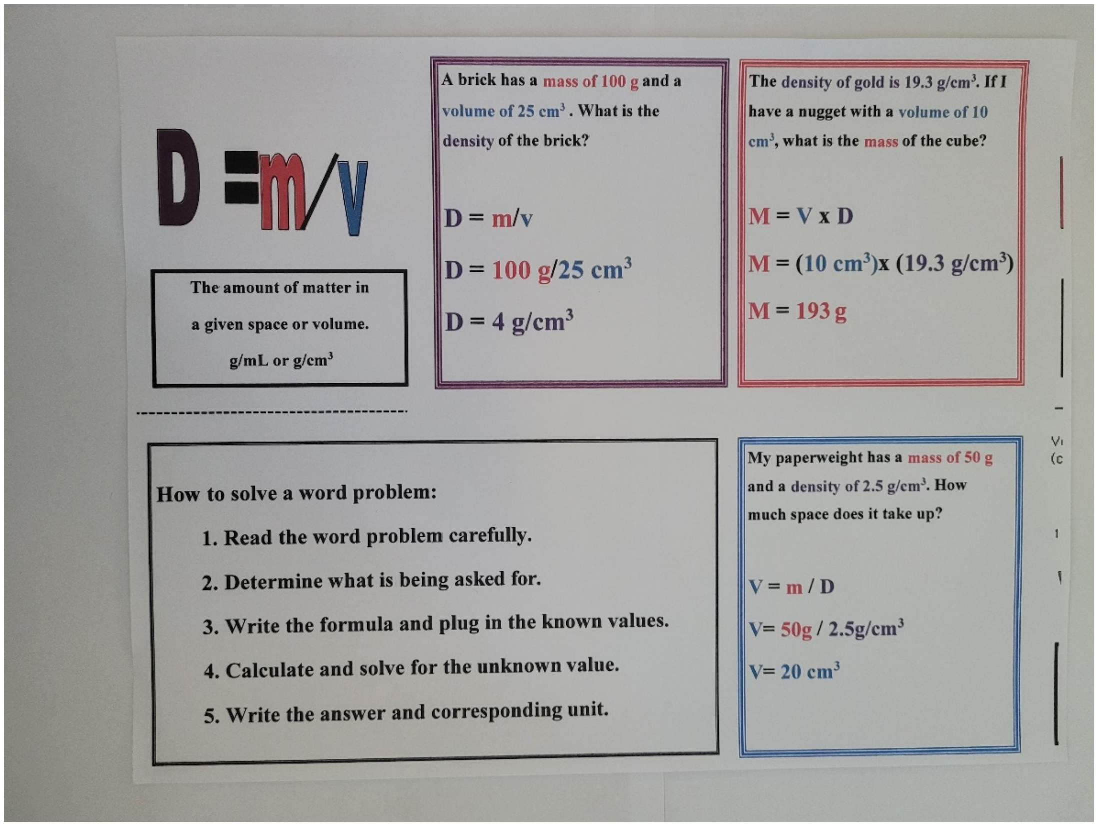
Matter

Related

Measure

APPENDIX D

DENSITY HANDOUT GIVEN TO ALL STUDENTS FOR NOTEBOOKS



APPENDIX E

STUDENT PAPER AND RUBRIC USED FOR CER EXPLANATIONS ALL YEAR LONG

Claims, Evidence and Reasoning = Quality Scientific Explanations

Big Question:

Science background - Describe the key science ideas you learned (or knew). This can be done before or after the experiment.

Claim – What is the answer to the "big" question? This is your hypothesis. If IV….., then DV…..

Evidence (data)	Evidence (data)	Evidence (data)

Reasoning – I found (describe evidence), and that supports my claim that ___________ because of (connect to what you learned/knew about this science idea).

Appendix B: Base Explanation Rubric

Component	Level		
	0	1	2
Claim—A 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.
Evidence—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.
Reasoning—A justification that links the claim and evidence. It shows why the data count as evidence by using 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—but not sufficient—scientific principles.	Provides reasoning that links evidence to claim. Includes appropriate and sufficient scientific principles.

CER Template modified from E. Brunsell, Edutopia
Rubric from K. McNeill and J. Krajcik, NSTA

APPENDIX F

Final Project for 8th Grade Students Using CER

INDIVIDUAL CLIMATE CHANGE RESEARCH PROJECT

1. Choose a topic related to climate change that inspires you. Write down a claim statement that goes with the topic (see list on back of page for possible topics). All topics must be checked in with Mrs. Nardiello.

Remember a good explanation of something has a:

Claim: What you know?

Evidence: How you know that?

Reasoning: Why your evidence supports your claim?

2. Gather evidence through research and use reasoning to explain why your evidence supports your claim. (This should take 2-3 class periods)

3. Prepare a presentation about your topic. (Think powerpoint, imovie, or poster) (This should take 2-3 class periods)

4. This is **not** intended to be a research paper **nor** **completed at home**.

Project Checklist:

Claim

_____ A. Choose a claim statement.

Evidence

_____ B. Choose two important relevant vocabulary terms and define in your own words.

_____ C. Provide a summary of your topic (general overview of the problem, solution etc).

_____ D. Include 3 convincing pieces of evidence that support your claim from 3 different reliable sources. (**Google is NOT the source).**

_____ E. Have at least 1 graph used to present information that supports your argument. You should be able to fully explain the graph including the details and main message.

_____ F. At least 2 appropriate pictures or diagrams that strengthen your argument or help explain, document or visualize the evidence.

_____ G. Minimum of one map related to your topic that strengthens your argument, include date and source.

Reasoning

_____ H. Explain how all your evidence supports your claim.
_____ i. Tell us about one "thing" you are willing to commit to that will make a positive impact on climate change. Be clear about how your commitment will have influence (try and link your positive impact back to your evidence).