THE 5E INSTRUCTIONAL MODEL FOR THE NEXT GENERATION CHEMISTRY CLASSROOM

by

Amy M. Chase

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DEDICATION

To the two lights of my life, Logan and Brooke, thank you for making me a better person. I hope you always convey a desire to learn and pursue goals. To my loving parents Thomas and the late Barbara Fabin, and brother Robert, your positive influence and constant encouragement throughout my life has been unmeasurable.

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ABSTRACT

The purpose of this study was to determine if scientific literacy skills centered on the Science and Engineering Practices from the Next Generation Science Standards would be impacted by the 5E Learning Cycle pedagogy. One hundred and three high school general chemistry students participated in this study which took place over the course of four units. Students participated in pre and post treatments that included the Scientific Literacy Skills Exam, the Science and Engineering Practice Survey, and the Elements of Science Learning Survey. In addition, student performance was evaluated on a pre- treatment laboratory rubric scores and four treatment scores.

Results suggest an attitudinal and cognitive gain in students' literacy skills gained during the 5E instructional units. The most growth occurred within the Science and Engineering Practice of planning and carrying out investigations, where the highest scores were seen in normalized gain value in rubric comparisons. In addition, this practice received the highest number of student responses to most focused on practice and highest percentage of gain during the Test for Scientific Literacy.

INTRODUCTION AND BACKGROUND

This study was conducted at Lewiston High School (LHS), a public urban sophomore through senior level high school in the town of Lewiston, Idaho. Lewiston is in Nez Perce County and sits along the Oregon, Washington and Idaho interface. It is bordered by the Snake River to the west, which separates Clarkston, Washington from Lewiston, and the Clearwater River to the North. Lewiston's population is 32,401 and is predominantly a blue collar town with strong industrial and agricultural influences. Lewiston Senior High School is the only secondary high school for the town with two feeder junior high schools for grades seven through nine. LHS is ranked at the low end of 5A (very large) school with a current population of 1038 students. There is a homogeneous distribution of males to females where 87% of the student body is identified as Caucasian (Lewiston Independent School District No. 1, 2016). This high school has recently been awarded a four-star ranking on a five star scale by the state of Idaho. The rankings in Idaho's school accountability system are based on the number of students enrolled in advanced courses and performance on SAT and other standardized assessments.

Three levels of junior chemistry are offered at LHS. Honors chemistry holds the prerequisites of higher level math and science along with teacher recommendations. This course is designed to engage students at a higher level along with covering more content. General chemistry is designed for students currently enrolled in Algebra II and who have had success in previous science courses. Students enrolled in this course will be given the Idaho state end-of-course assessment in chemistry. Basic chemistry allows students to explore science who have typically been unsuccessful. This study focused on general chemistry students.

Lewiston school district adopted the Next Generation Science Standards (NGSS) in lieu of the Idaho Science Standards the fall of 2014. This change required teachers and students to think differently where students become the masters of their learning. Lewiston science classrooms have slowly shifted curriculum from a teacher-centered focus to student-centered learning.

The integration of NGSS has been a slow process. Most teachers have decided to begin with one to two units the first year and have progressed with multiple units the fall of 2015. However, science educators would not consider themselves fully transitioned to NGSS. One obstacle faced is that the Idaho standards are very specific where the NGSS standards are general and encompass a variety of concepts within one standard.

While preparing for the second year of NGSS adoption and also taking into consideration the Idaho standards, a new lesson plan format was essential to serve as the basis of chemistry unit preparation. The 5E lesson plan template was chosen for several reasons. First, the format was easily implemented into current practices that already focus on student-centered learning. Secondly, it allowed foci to shift to students building valid claims that are supported by evidence. The 5E lesson plan allows for easy implementation of the Science and Engineering Practices. In addition, this template is easy to format and follow.

All of this led me to the development of the following focus question, *How does the integration of the 5E instructional model impact student growth of the NGSS Science and Engineering Practices?* The following sub-questions were addressed,

- Does a curriculum that emphasizes the NGSS Science and Engineering Practices affect students' ability to apply scientific literacy skills?
- How does the implementation of the 5E lesson model impact students' attitudes towards scientific processes?
- Does a curriculum that emphasizes the Science and Engineering Practices influence students' ability to articulate experimentation?

CONCEPTUAL FRAMEWORK

The necessity to improve science education to meet the evolving needs of K-12 twenty-first century learners is indisputable. Students are faced with a vast range of technological, scientific and cultural changes that were absent in previous generations. There is a need to incorporate hands-on experiences centered on scientific literacy in order to prepare our children to face an ever-changing world. At the center of this form of learning is scientific inquiry. The purpose of inquiry is to engage students in activities and the thinking processes of scientists and to develop an understanding of the important concepts, principles, and methods in science (Ruiz-Primo et al., 2010).

The National Research Council (NRC), composed of leading scientists from across the United States, developed a framework to act as the foundation for a new set of national standards. The Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas was designed to engage all students in science and engineering practices that apply interdisciplinary concepts to deepen understanding. Furthermore, it emphasized developing knowledge in science equally with an understanding of scientific practices (National Research Council, 2012).

The Next Generation Science Standards (NGSS), published in 2013, approaches curriculum as three-dimensional where students authenticate knowledge through demonstration and application (NGSS Lead States, 2013). The Framework's three dimensions, forming the basis of the NGSS, are science and engineering practices, disciplinary core ideas, and crosscutting concepts (National Research Council, 2012). Science and engineering practices focus on how scientific knowledge develops through investigation. Science is explanatory and engineering is applicatory.

Crosscutting concepts hold value across science and engineering to provide an organizational way for students to compartmentalize concepts. These concepts, or themes, help develop a coherent and scientifically based view of the world (National Research Council, 2012). The seven crosscutting concepts presented in Chapter 4 of the Framework are as follows:

1. Patterns
2. Cause and effect
3. Scale, proportion and quantity
4. Systems and system models
5. Energy and matter
6. Structure and function
7. Stability and change

Disciplinary core ideas identify essential topics in physical, life, earth and space sciences as well as engineering, technology and application. The framework specifies that each performance expectation incorporates a relevant practice of science or engineering, with a core disciplinary idea and crosscutting concept. This guideline is what sets the NGSS apart from previous standards which only focused on understanding of core concepts (Andersen, 2013; National Research Council, 2012).

There are eight science and engineering practices that serve as the underpinnings of the NGSS. These practices have all too often been underemphasized in the context of science education, but are critical to achieving students that can reason scientifically (National Research Council, 2012). Each practice is broken into categories based on grade level ability where standards progressively become more refined. The practices bring reasoning and skills forward to demonstrate scientific knowledge. In addition, the practices help students formulate understandings of the other two framework dimensions to make knowledge more meaningful. These practices also allow the learner to mimic those of professional scientists and engineers. The eight practices include the following:

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence

8. Obtaining, evaluating, and communicating information

Students begin the experimental process by determining an inquiry problem or design idea through the process of asking questions. These questions should be inspired by the need to solve a problem. Scientific questions are well defined and are supported with empirical evidence. Engineering questions begin with defining a problem where no one correct solution exists (National Research Council, 2012).

Modeling in science and engineering is vital to understanding the world around us. Eykhoff (1974), described models as “a representation of the essential aspects of an existing system (or a system to be constructed) which represents knowledge of that system in a usable form” (Edgar, 2013, p.1). In science, a model seeks to explain a phenomenon while in engineering they are used for prototyping. The goal of modeling should be to develop models, construct drawings, use simulations and test designs. Mental models help the learner understand the world around them by personal, idiosyncratic experiences. This type of model varies from person to person because our experiences and perceptions are unique. The NGSS wants the learner to make conceptual models, which are clear and analogous therefore not based on perception. Examples of conceptual models include diagrams, replicas, analogies, mathematics, simulations and prototypes (Andersen, 2013).

Planning and carrying out investigations should “Range from those structured by the teacher to those that emerge from students’ own questions” (National Research Council, 2012, p. 61). Over time, students are expected to become more systematic and careful in their methods. For example, in high school, students should be expected to define, control and manipulate variables accordingly. Students at all levels should be expected to collect data, both qualitatively and quantitatively (National Research Council, 2012).

Students learn to analyze and interpret data through mathematics and computational thinking. Students derive meaning in science and test solutions in engineering from their investigations. At the higher levels, the learner should be able to choose the method of analysis, including the correct type of graph to display data. In addition, they should be able to derive meaning from science and test solutions in engineering (Andersen, 2013).

The ability to synthesize and apply mathematical concepts is essential in every field of science and engineering. The use of computation allows the learner to represent physical variables and their relationships in quantitative ways. Students are expected to use laboratory tools connected to computers for observing, measuring, recording and processing data. The use of computers also allows students to synthesize large amounts of data and automate calculations (NGSS Lead States, 2013).

A major component of inquiry is the ability to validate knowledge. Through constructing explanations, students make connections between knowledge, its connection to evidence, its uncertainty, and its subjectivity to change (Ruiz-Primo, 2010). While constructing concepts, students demonstrate their own understanding of the implications of a scientific idea. Through written expression, students are able to reflect on knowledge by exploring gaps, misconceptions and relationships between ideas. Ruiz (2010) states, “The construction of written scientific explanations should be considered the heart of scientific inquiry and should be emphasized in every science class.”

“Scientific argumentation is a mode of logical discourse whose goal is to tease out the relationship between ideas and the evidence” (Duschl, 2007, p. 33). Students should be taught that scientific argumentation is how knowledge is processed and refined. Being literate in science and engineering requires the ability to read and understand literature. At a young age, students should be asked to engage in the communication of science, especially regarding the investigations they are conducting and the observations they are making (NGSS Lead States, 2013).

Because the eight science and engineering practices are reliant on each other, advances in one will promote advances in others. The overlap is unavoidable. For example, if you are focusing on a lesson where students are arguing from evidence, they must also be able to analyze and interpret their data, and have already planned and carried out the investigation (Grooms, 2015). In fact, the practice of scientific argumentation can foster students understanding of science content and be part of the core of scientific investigations.

In 2006, the NRC proposed to structure science lessons as integrated instructional units where laboratory experience is interwoven with other activities. These integrated units enhance student achievement. Bybee et al. (2006) states, “Research indicates that integrated instructional units are more effective than typical laboratory research for improving mastery of the subject matter, developing scientific reasoning, and cultivating interest in science” (Effectiveness, para. 9). Students should be involved in the scientific process where new knowledge is built from preconceived notions. In addition, diagnostic, formative assessments should be embedded into the instructional sequence to gauge students developing understanding (National Research Council, 2006).

The BSCS 5E instructional model, developed in the 1980's, exemplifies the integrated unit approach. Lessons are developed around five phases: engage, explore, explain, elaborate, and evaluate. During the engage phase, a question, problem or discrepant event is proposed with the intention of capturing the learner's attention. Students should be left thinking about the content related to the learning outcomes from this phase. In the second phase, students explore with hands-on experiences to try to clarify elements from the previous stage. Then, the teacher directs attention to key concepts during the explanation stage. During elaboration, an extension of the learning is proposed to enrich concepts. Students assess their understandings and teachers evaluate progress in the last phase of this learning model (Bybee, 2014; Bybee, 2006).

Bybee discusses that the 5E instructional model can be used for developing single lessons, instructional units or an entire curriculum. He suggests, "The optimal use of the model is a unit of two to three weeks where each phase is used as the basis for one or more lessons" (Bybee, (2006) p.11-12). In addition, phases can be used more than once when appropriate, but should not be omitted all together. In some cases, phases can be added such as and elicit of prior knowledge before the engage phase (Bybee, 2006).

Lawson (1995) completed a comprehensive review of 50 research studies on the 5E learning cycle. In regards to scientific reasoning, the 5E model showed higher achievement scores than other models in 17 of 18 studies. Included among the reasoning skills are areas of scientific inquiry, asking questions, experimental design, and developing and communicating results (Lawson, 1995; Bybee, 2006).

METHODOLOGY

The purpose of this study was to determine if scientific literacy skills centered on the Science and Engineering Practices (SEP's) from the Next Generation Science Standards (NGSS) would be impacted by the 5E Learning Cycle pedagogy. The subjects of this study were 103 high school general chemistry students. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

The project encompassed planning and implementing four 5E lesson plans that met high school NGSS in chemistry over a three month period. Students were also given direct instruction on each of the eight SEP's throughout the treatment with emphasis placed on specific practices where applicable. Lesson plans were administered during 85 minute block periods where students met every-other day.

The units chosen for this treatment centered on chemical reactions, stoichiometry and chemical engineering (Table 1). In order to fit the unit design, each unit was created with slight variations to the 5E model. The Petroleum to Plastics unit rearranged 'E' components and included a background section. During the Chemical Reactions unit, the hands on experience was introduced during the *Explain* component rather than the *Explore* component. Our Thermite was designed to create a transition between the Chemical Reaction and Stoichiometry unit. This unit was shorter in length than the others at one and a half block periods. The Air Bag Project incorporated multiple cycles of 5E within one unit (Appendix B).

Table 1
NGSS Performance Expectations for Treatment Units

Main Standard: HS-PS1 Matter and it's Interactions

Unit of Study	Performance Expectation	Standard
Polymerization: From Petroleum to Plastics	HS-ESS3	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
Chemical Reactions	HS-PS1-2	Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
Introduction to Stoichiometry- "Our" Thermite Reaction	HS-PS7	Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
Airbag Design Project	HS-PS1- 6	Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium
	HS-PS7	Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
	HS-PS3- 3	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
Engineering Components: Petroleum to Plastics and Airbag Design Projects	HS-ETS1- 3	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
	HS-ETS1- 2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Students were administered the Test of Scientific Literacy (TOSL) as a formative assessment (Appendix C). This test was designed for an intermediate level audience to assess reasoning skills rather than content. Students were given 30 minutes to complete the TOSL's 20 question multiple choice assessment. For each question, scientific literacy skills were correlated to a corresponding SEP's (Table 2). The test was administered prior to the first unit of study and again after the last unit of study, compared using box and whisker plots and analyzed using normalized gain (Russell, n.d.).

Table 2

Scientific Literacy Pre and Posttest Correlation to S&E Practice

Skill	Description	S&E Practice	Question
1	Identify a valid scientific argument(e.g., recognizing when scientific evidence supports a hypothesis)	Engaging in Argument from Evidence	1, 6, 16
2	Conduct an effective literature search(e.g., evaluate the validity of sources)	Obtaining, Evaluating and Communicating Information	5, 13 15, 17
3	Evaluate the use and misuse of scientific information(e.g., recognize a valid scientific course of action)	Obtaining, Evaluating and Communicating Information	7
4	Understand elements of research design and how they impact scientific findings/conclusions (e.g., identify strengths and weaknesses in research)	Planning and Carrying out Investigations Engaging in Argument from Evidence	4 8 18
5	Make a graph	Analyzing and Interpreting Data	12
6	Read and interpret graphical representations of data	Analyzing and Interpreting Data	3, 9, 14
7	Solve problems using quantitative skills, including probability and statistics	Using Mathematics and Computational Thinking	10, 19
8	Understand and interpret basic statistics	Using Mathematics and Computational Thinking	2, 11
9	Justify inferences, predictions and conclusions based on quantitative data	Constructing Explanations and Designing Solutions	20

Average normalized Gain scores were analyzed using Hake's (1999) description of average normalized gain scores ranking of high, medium and low values. A high normalized gain value is classified as >0.7 a medium value as 0.3 to 0.7 and a low value as <0.3 (Hake, 1999). This description of high, medium and low average normalized gain values will be utilized through this study.

A customized laboratory rubric was created for each treatment unit (Appendix D). Each rubric served as the *Evaluative* component from the 5E instructional model. Each rubric focused on individual performance expectations within the unit as well as content-driven expectations. Science and Engineering Practices were also correlated within each of the rubric categories (Appendix E). Categorical Averages within the lesson plan rubric were combined with like SEP's and evaluated for progress using a histogram then analyzed for trends in data in one pre-treatment and four treatment rubrics (Wallace, 2005).

Learners were given a pre and post treatment Science and Engineering Practice Survey (SEP Survey) to determine their ability in identification and relevance ranking of the SEP's within their learning. Student responses were evaluated using a histogram and analyzed for trends in data (Appendix E).

Students completed the Elements of Science Learning survey both before and after the treatment (Appendix F). The Elements of Science Learning was intended to gain perception on student attitudes and confidence levels related to the process of science and how these changed over the course of the treatment. The questionnaire was designed to measure student attitudes toward science in three sections; self-efficiency or beliefs a student holds about their own abilities, interest or a student's level of curiosity about science, and value or importance of science, scientific knowledge and science-related activities (Williams, K., Kurtek, K., & Sampson, V. (2011)). Likert data generated from the Elements of Science Learning was analyzed for each of the 35 survey questions and ranked according to scores, lowest to highest. These averages were compared using a one-tailed t-test.

After individual components of the treatment units, students were randomly selected to complete the 5E Activity Interview (Appendix G). The interview was designed to add additional qualitative student input to the Elements of Science Learning and was analyzed for common themes.

A triangulation matrix was created to summarize the treatments along with sub questions (Table 3). Upon completion of the treatments, results for each data source were compared for common themes.

Table 3
Triangulation Matrix

	Data Source 1	Data Source 2	Data Source 3
Does a curriculum that emphasizes the NGSS SEP's effect students' ability to apply scientific literacy skills?	Scientific Reasoning Skills Test (SRST) (pre and post)	Laboratory Rubric	Student Interviews SEP Post Survey
How does the implementation of the 5E lesson model impact students' attitudes towards scientific processes?	Elements of Science Literacy Likert Survey (pre/post test)	Informal Teacher Observations	Student Interview SEP Post Survey
Does a curriculum that emphasizes the SEP's influence students' ability to articulate experimentation?	Elements of Science Literacy Likert Survey (pre/post test)	Laboratory Rubric	Student Interviews

DATA AND ANALYSIS

Pre-treatment rubric scores show high proficiency in developing and using models at a 75% success rate (*N*=100) (Figure 1). During this section, students were asked to research and include the complete chemical reaction for the oxidation of iron. Students also scored high in *obtaining, evaluating, and communicating information*. This science and engineering practice (SEP) was analyzed with three separate components within the lab, the title, reference, and presentation section. Students struggled the most with *analyzing and interpreting data*, with an overall score of 59.72% (Figure 1). This section was analyzed using the data section along with the analysis and evidence section of the pre-treatment rubric. Upon further comparison of the pre-treatment sub categories that comprised the *analyzing and interpreting data* score, 10 of 12 students scored lower in the analysis and evidence section compared to the data section. Students who lost points did not account for error in data and did not address calculations.

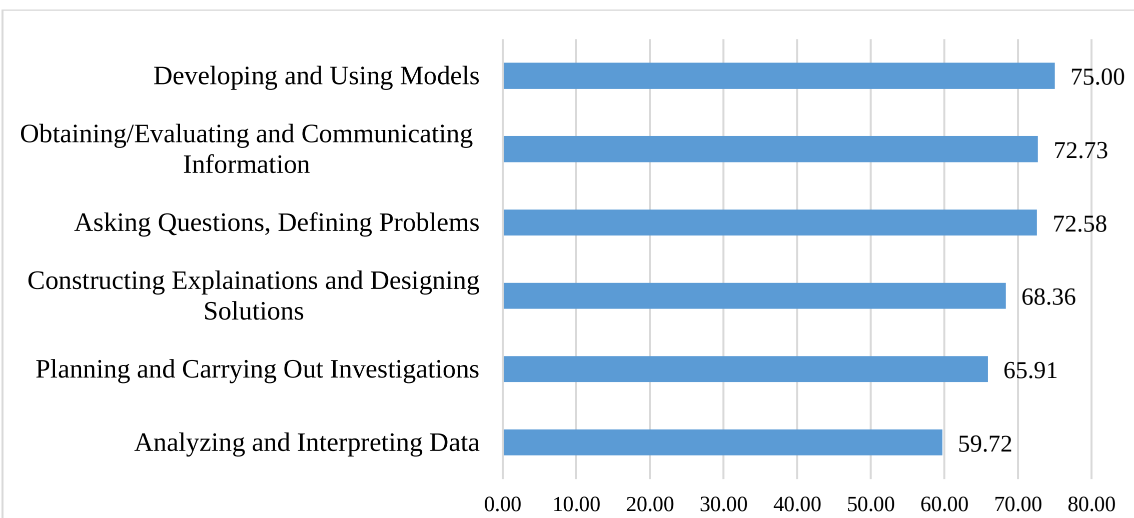

Figure 1. Pre-treatment unit correlation to NGSS Science and Engineering Practices, (*N*=100).

During the Petroleum to Plastics Unit, 88% of students were able to *ask questions* when given a prompt. In addition, students also showed high ability in *designing solutions* at 86.07% and *analyzing and interpreting data*, 83.98%. These sections correlated to a student inquiry investigation, *planning and carrying out investigations,* where 81.74% of students showed proficiency (Figure 2). Student overall scores in laboratory design, engineering and presentation components of this unit were the top six of seven scores, while the chemistry component was ranked seven of seven (Figure 2). *Developing and using models* was assessed by student explanations using ball and stick models for the chemical reaction of the polymerization of methane to plastics and received an overall proficiency score of 67.17% (Figure 2).

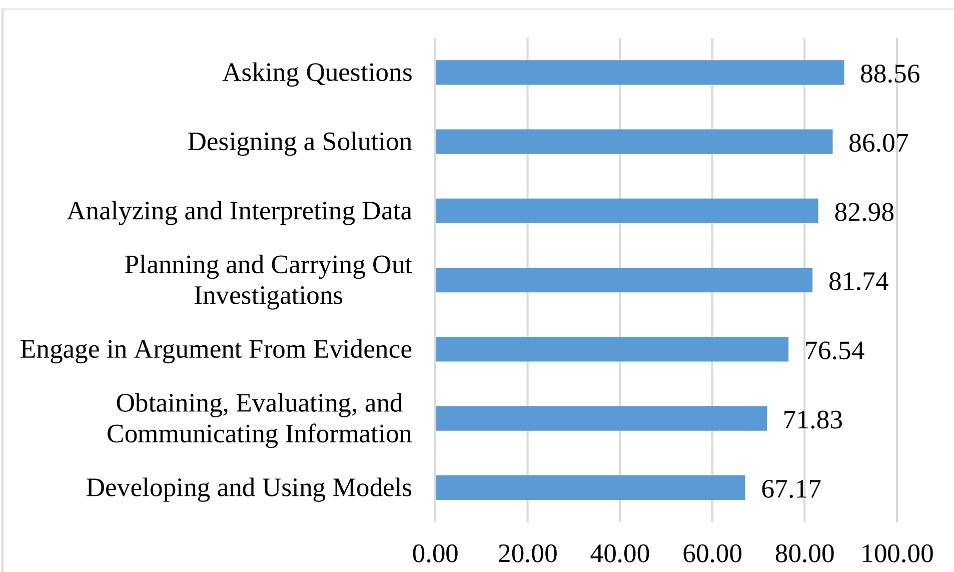

Figure 2. Petroleum to plastics student performance correlated to NGSS Science and Engineering Practice categories, (*N*=102).

Student scores showed high performance on the ability to write complete chemical reactions which correlated to the SEP, *developing and using (mathematical) models* (Figure 2). Students were assessed in the SEP, *planning and carrying out* *investigations* by basing experimental predictions on information given in the students hand out and the student written chemical equations. Student responses show 81% were able to correlate predictions to information read and the chemical reactions written prior to experimentation (Figure 2).

Constructing explanations was correlated to the experimental rubric when students were asked to make sense of observations and *engaging in argument from evidence* was utilized when students explained experimental observations using the balanced chemical equation. Seventy four percent of students were able to formulate good observations while only forty percent were able to show proficiency in tying the observations back to the chemical reaction (Figure 2).   I awarded partial credit for the following answer in column four, *engaging in argument from evidence*, and full credit in column three, *constructing explanations*: "The BTB (bromothymol blue) will stay blue because it is a base." If this student would have stated, "The product, calcium hydroxide is a base, therefore the BTB stays blue," I would have awarded full credit in both columns. Many students simply stated, "The solution was blue," resulting in no points rewarded for column four and partial points for column 3 (Figure 2).

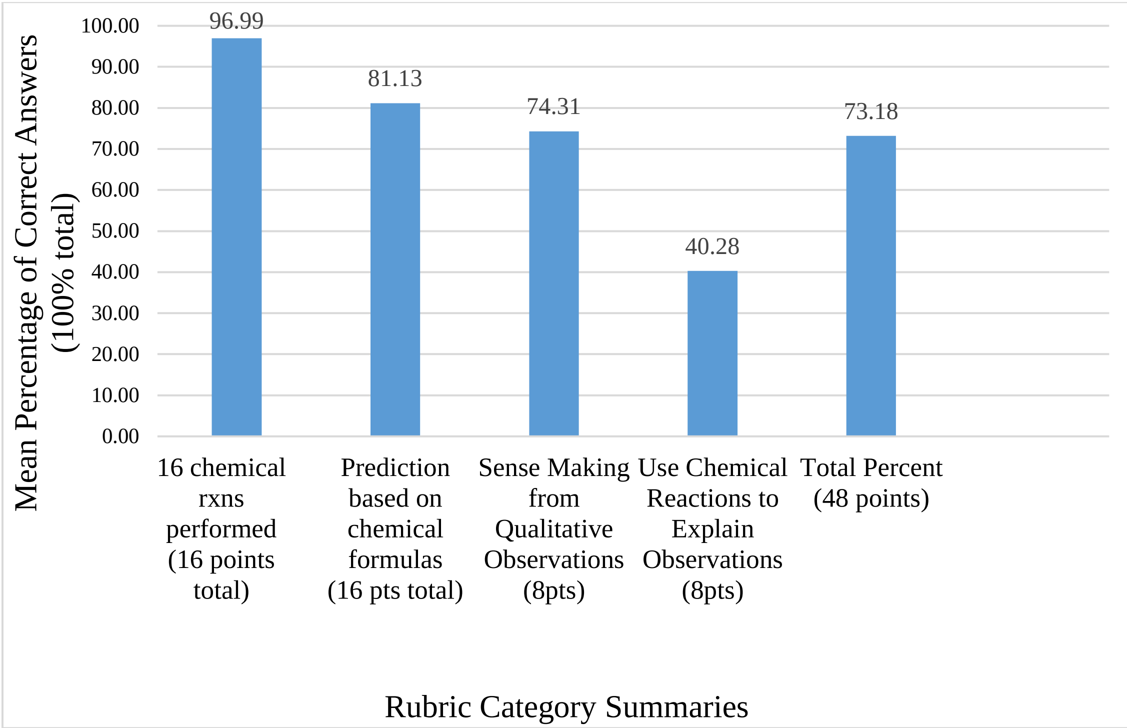

Figure 3. Chemical reactions laboratory rubric correlation to NGSS Science and Engineering Practices, (*N*=98).

During the "Our" Thermite Reaction, student scores show a slightly higher competency of 87.33% in their explanation of individual error values compared to 79.00% for their explanations in class data (Figure 3). Several students were marked down due to lack of evidence to support their data. Obtaining, evaluating and communicating information was assessed during this lesson when students were asked to respond to the overall individual and class data. Their use of scientific and technical terms were analyzed on a three point scale. Students were 75.00% successful at communicating experimental results in a scientifically appropriate manner (Figure 3).

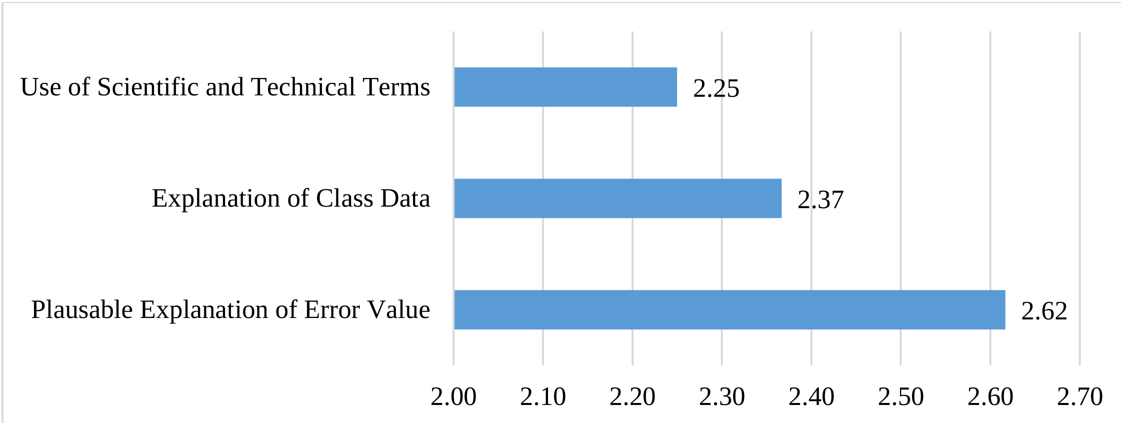

Figure 4. "Our" thermite reaction rubric correlation to NGSS Science and Engineering Practices, (*N*=96).

Student scores during the Airbag Project indicate a high understanding in areas related to engineering and design where slightly lower scores were observed in areas related to the use of stoichiometric calculations (Figure 5). The use of computational thinking received a class average of 80.59%, with the highest percentage of point deductions for stoichiometric inaccuracies in video explanations. Students also lost points for vague or inaccurate explanations of the chemical reactions from the unit which accounts for the 13.59% reduction in developing and using models category (Figure 5).

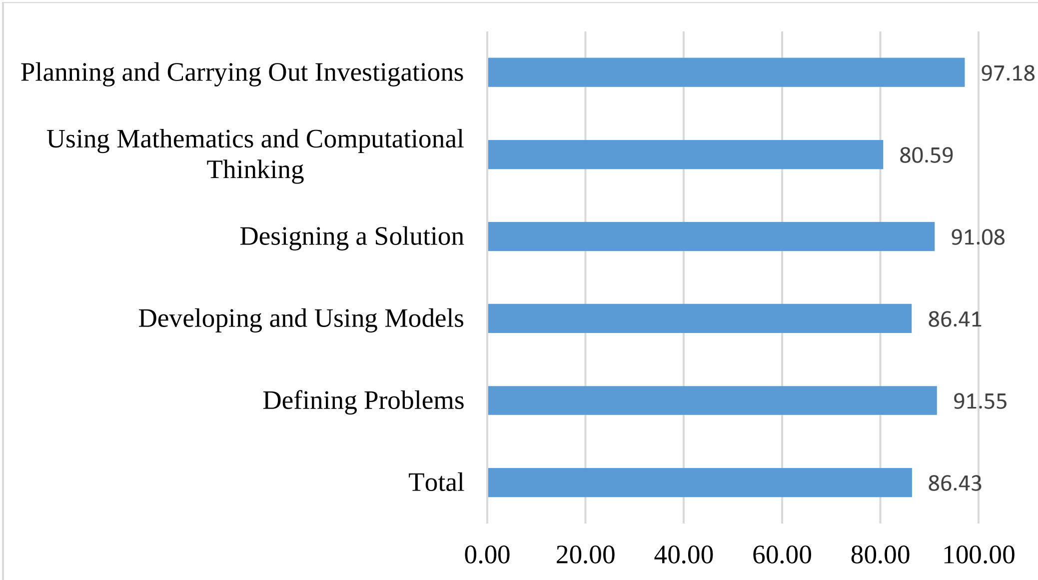

Figure 5. Airbag project rubric correlation to NGSS Science and Engineering Practices, (*N*=92).

The mean SEP categorical data showed middle normalized gains in five of six SEP categories (Figure 6). Students showed the most growth in asking questions and defining problems, with a medium gain of 0.6373, followed planning and carrying out investigations, with a gain of 0.6094 (Figure 6). A low gain score was seen in the SEP practice of *obtaining, evaluating and communicating information* of 0.02511 (Figure 6).

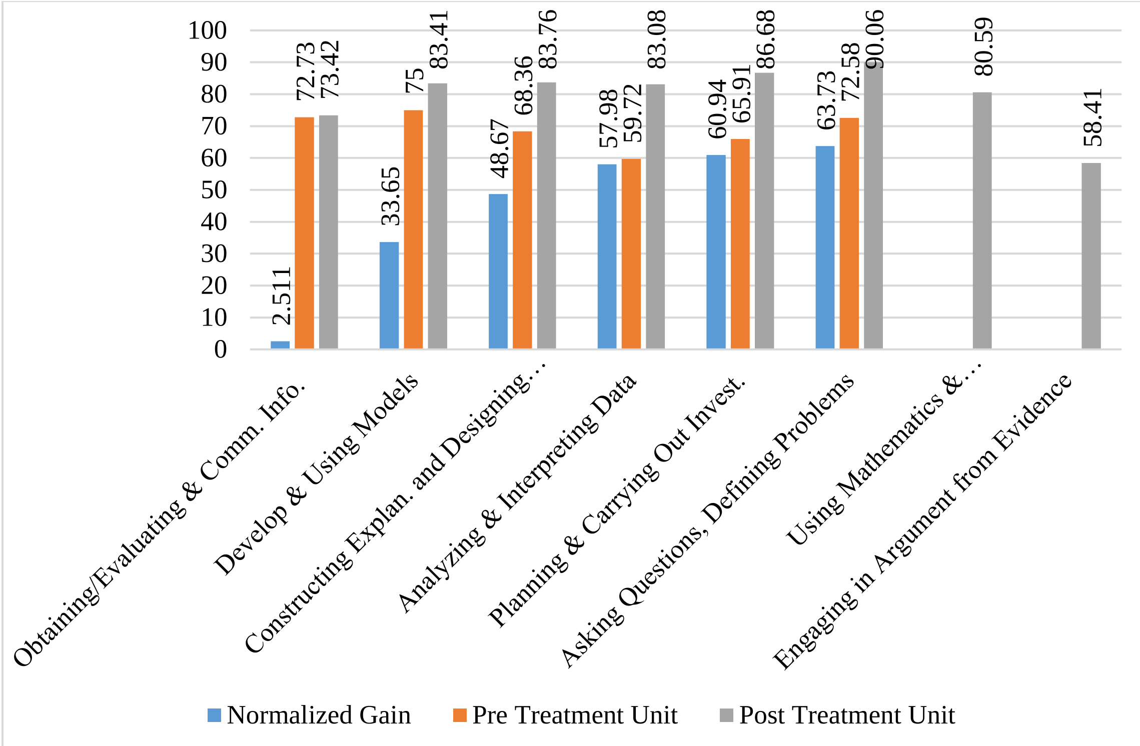

Figure 6. 5E lesson plan rubric pre and post treatment correlation to Science and Engineering Practices, (*N*=92).

The twenty question *Test for Scientific Literacy* (TSL) showed a slight increase in overall class scores with a pre to post-test mean increase of 10.00 to 11.05 (Figure 7). In addition, students normalized gain values showed that 23 students had a medium positive gain based on their growth potential between the TSL pre and post-test, 57 students showed low normalized gain and 23 students showed a negative gain in value (Figure 8).

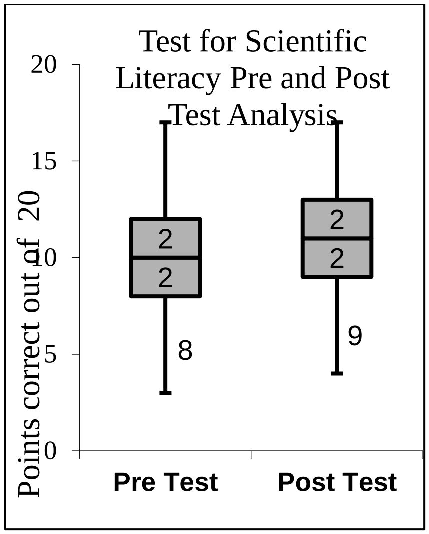

Figure 7. Test for scientific literacy pre and post- test point values, (*N*=103).

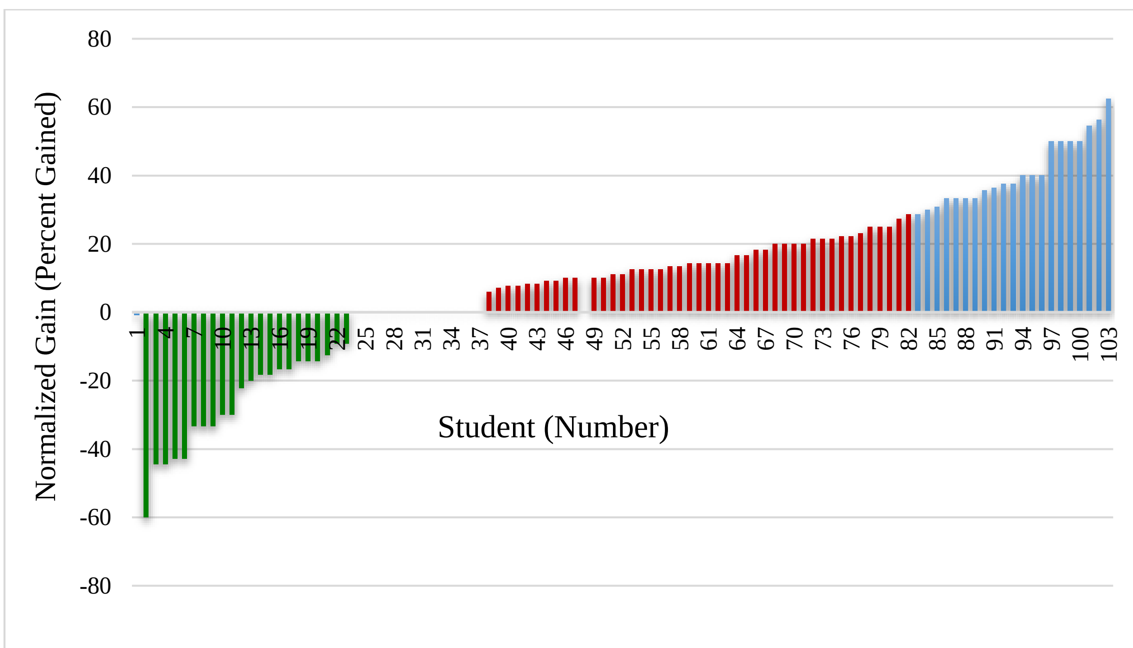

Figure 8. Test for scientific literacy normalized gain values: Negative (<0%), low (<30%), middle (30%-70%) and high (>70%) gains, (*N*=103).

Students showed the highest gain of 8.15 percent in the SEP category of *planning and carrying out investigations* during the Test for Scientific Literacy (TSL) (Figure 9). This category also comprised the highest amount of test questions at 5 out of 20. The lowest difference in value was seen in the SEP category of *constructing explanations and designing solutions*, with a value difference of 3.32 percent. This category was comprised of a total of one question (Figure 9).

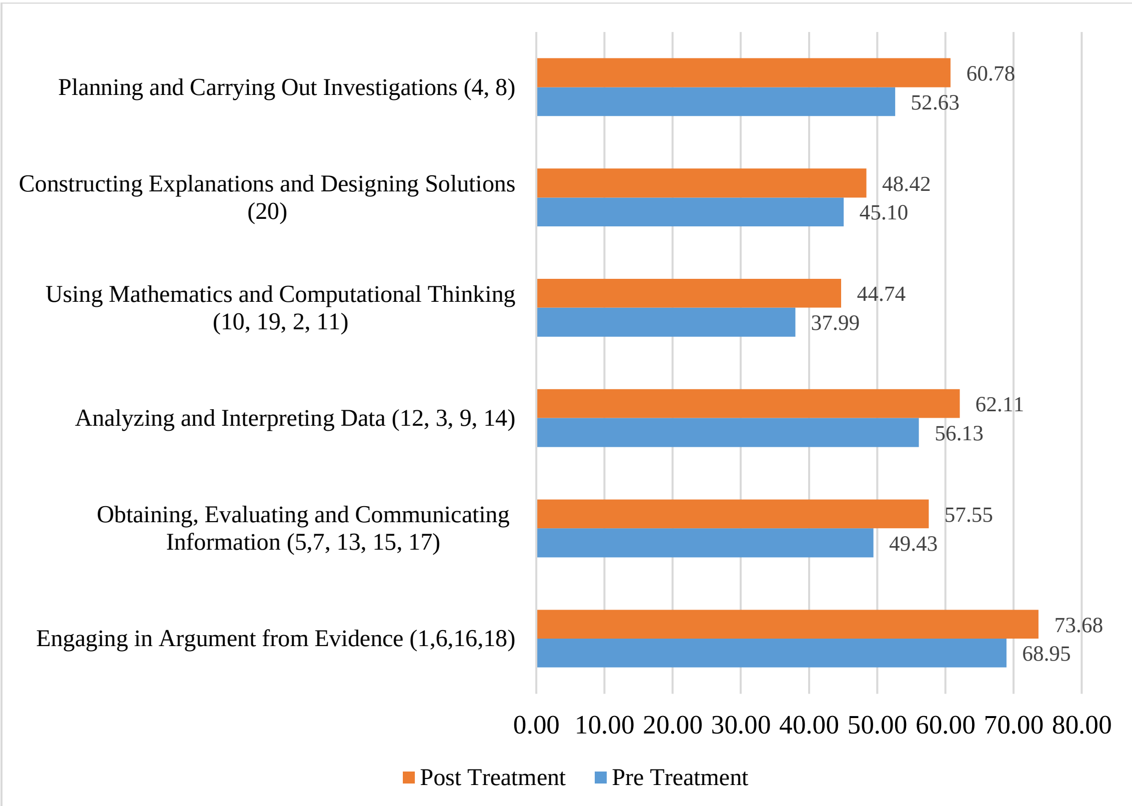

Figure 9. Science and engineering practice standard correlated to Test for Scientific Literacy test question, (*N*=103).

When asked to determine a single SEP as the focus of the lesson, *planning and carrying out investigations* was selected 20% of the time, followed by developing and using models and using mathematical and computational thinking, both with 18% of responses (Figure 9).

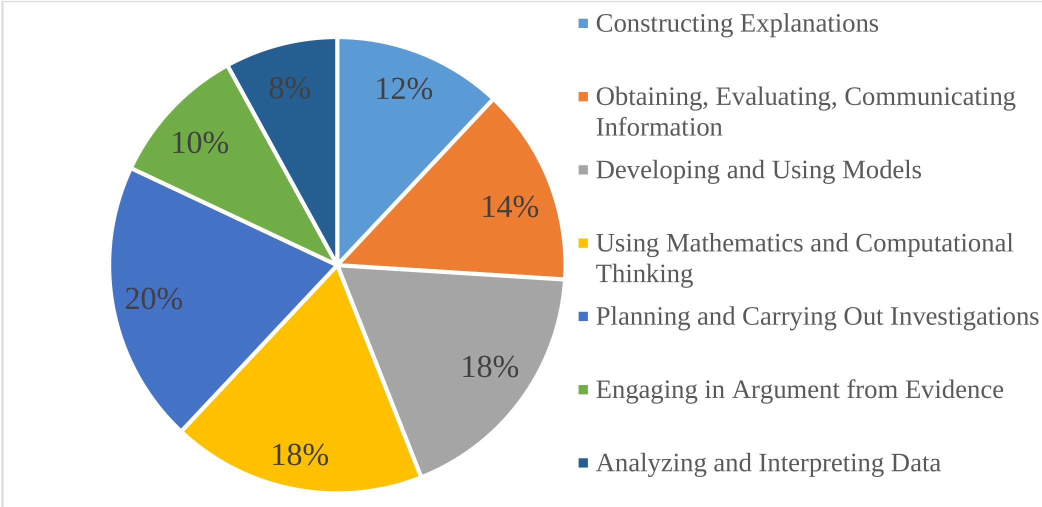

Figure 10. Culminating treatment responses to interview question, *what science and engineering practice did we focus on in today's lesson*, (*N*=50).

During the interviews, no student responded that the focus of the lesson was on *asking questions and defining problems*, however, during the SEP survey students ranked this practice as the most used on both the pre and post survey (Figure 10). *Engaging in argument from evidence* scored low on the interview, at 10% (Figure 10). This SEP also had the lowest responses during the SEP survey ranking of application at 2.40 out of 8 (Figure 11). In contrast, during the interview, planning and carrying out investigations scored the highest at 20% while in the post SEP survey, scored 5.35 out of 8 (Figure 10, Figure 11).

Pre and post treatment data on the SEP survey revealed the largest decrease in ranking for the SEP of *obtaining, evaluating and communicating information* with a -1.02 ranking (Figure 11). When compared to the interview data, this SEP ranked four out of eight in responses (Figure 10). In contrast the SEP category that showed the largest increase was *developing and using models* with an increase in ranking of 0.93 (Figure

11). When compared to the interview data, developing and using models ranked two out of eight in responses (Figure 10).

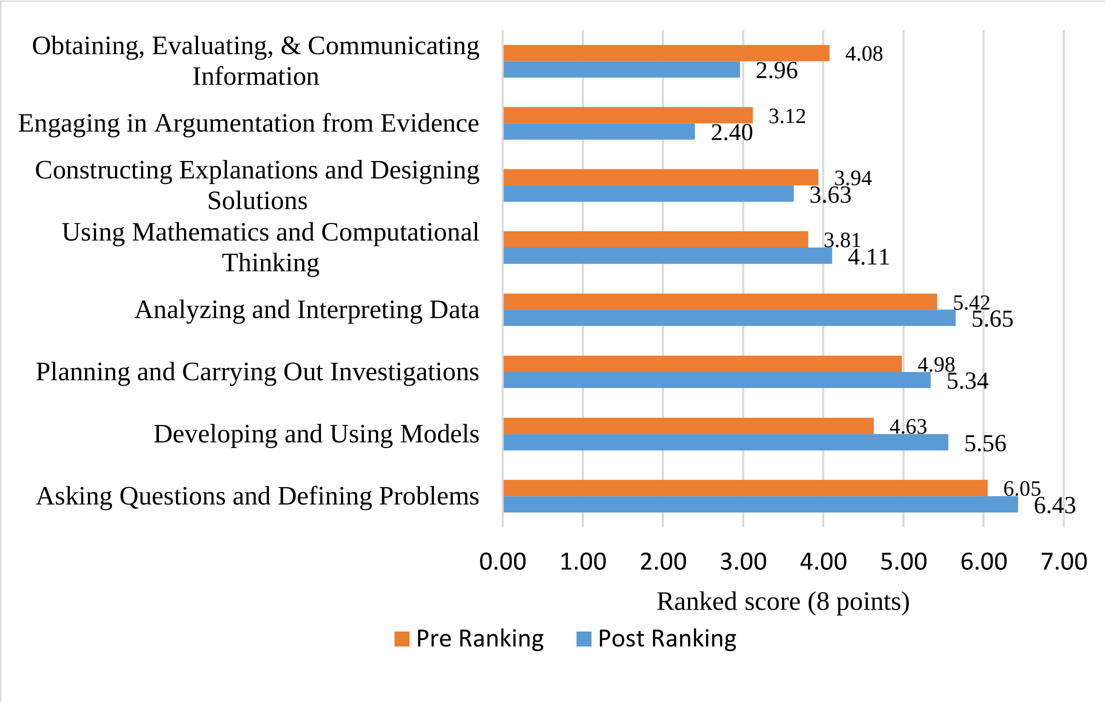

Figure 11. Science and Engineering Practice ranking responses from 1-8, 1 being the most used Science and Engineering Practice. Graph shows ranked score on an 8point scale, (*N*=103).

Student Likert responses on the Elements of Scientific Literacy Survey showed a gain in value from the pre-treatment to post-treatment survey in 27 out of 35 response questions. Four out of five of the top gains were in categories related to the scientific process (Figure 12). Student mean differences were highest on questions, *I like planning scientific investigations* (0.53), *I like solving scientific problems* (0.45) and *I am confident I understand science* (0.41) (Figure 12).

Negative values were seen in questions, *I think doing well in science is important* (-0.12), followed by *good jobs require science* (-0.09) and *I want to succeed in science* (-0.09) (Figure 12). In addition, students showed no growth in questions, *I want* *to understand scientific concepts*, and *science is important* (Figure 12). Many student comments from the survey discussed their enjoyment for science, but their indifference in perusing a career in a scientific field. One students stated, "Science is something that I find an interest in, but I do not really plan on going into a career with science at this point in time. I like attaining the knowledge and find it interesting."

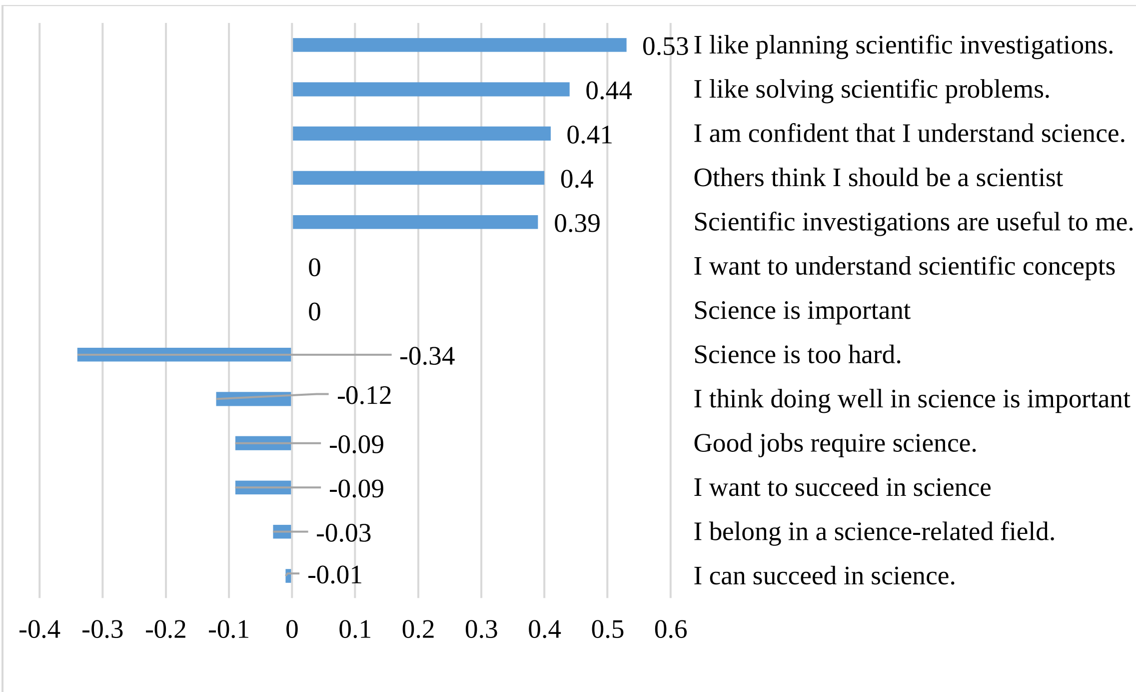

Figure 12. Average difference in values of pre and post treatment elements of science learning responses, (*N*=103).

A t-test performed on the mean differences between the pre and post treatment responses to Elements of Science Learning survey questions revealed no significance in values (Table 4). Based on a two-tail test, the statistical t value, of 1.4458 falls below the T- critical value of 3.00, proving no statistical variance between pre and post-treatment responses (Table 4).

INTERPRETATION AND CONCLUSION

The implementation of 5E instructional model along with the science and engineering practices (SEP's) had a positive impact on students' attitudes towards the scientific processes. Forty six out of fifty students interviewed preferred 5E learning completed during the treatment unit verses other forms of learning. In addition, student attitudes towards science in their own beliefs about their abilities, level of curiosity about science and the importance of science improved in 29 of 35 questions from pre-treatment to post-treatment values.

Students' ability to apply scientific literacy skills improved throughout the course of this study. A slight improvement was measured in the Test for Scientific Literacy (TSL). In addition, normalized gain values in rubric scores showed medium growth in five of six SEP's tested. Student responses to interview questions placed the SEP practice of *planning and carrying out investigations* as the most focused on practice throughout the course of the treatment units. In addition, this practice showed the highest normalized gain value in the pre and post treatment rubric correlation during the Test for Scientific Literacy (TSL) treatment.

Students were able to show improvement in their abilities to articulate experimentation throughout the course of study. TSL score improvements show students were able to apply SEP's utilized in hands-on experiences to other scenarios. The pre-treatment and treatment rubric scores also show a transitional shift in SEP's emphasizing experimental design. I have also observed students utilizing the scientific process more throughout hands-on experiences. For example, after introducing the airbag project, students immersed themselves in their project designs and asked few questions relating to science and engineering. Instead, they reasoned and researched for themselves. It was the first time I had witnessed full constructivism from my students.

Overall, a curriculum taught through the 5E instructional model which emphasized the NGSS did impact student learning. Through hands-on experiences, students were able to connect with the scientific process. One students stated that, "The hand on learning allows me to remember what we were learning. Like a point of reference." The connections made through the 5E models developed will serve as this point of reference for future core concepts.

VALUE

In order to fully develop lessons which adhere to the Next Generation Science Standards (NGSS), the lesson design must account for all three dimensions. This action research-based classroom project has taught me how to look at unit design through the lens of the science and engineering practices along with principle core ideas which were addressed in the unit design. However, I neglected to pinpoint crosscutting concepts within the lesson design (Appendix B). In the future, I would further dissect each standard identified by aligning the crosscutting concepts to each lesson from the standards addressed.

Two of the units in the study were new, and two were previously taught. Each unit presented a unique challenge in molding the content either to the 5E lesson plan model or to the NGSS standard/SEP practices. I made the 5E lesson model unique to specific situations. For example, in the chemical reactions unit, students explored with modeling while writing chemical reactions. Then, during the explain component, students participated in the hands-on activity. This approach was flipped from the traditional 5E model because students used the hands on activity to explain their learning.

The low score observed in the chemical reaction rubric category using chemical reactions to explain observations, impacted student ability to perform well on the content-driven assessment. This category directly related to the SEP practice of *engaging in argument from evidence*, where I wanted students to explain their observations by using their balanced chemical equations. Most students did not connect their observations to the chemical equations and a disequilibrium in learning occurred. In the future, I plan to incorporate peer editing and *engaging in argument from evidence* to allow learners the opportunity to learn and teach through each other's explanations.

I find value in the lesson plan format utilized throughout this project, and plan to incorporate it with future units, with modifications. In addition, I have added the word, *Elicit,* above the starter white board to indicate eliciting prior knowledge. I have also found students starting to become more independent learners, relying less on direct instruction and answers. I wanted to find a model which engaged the learner in hand-on learning, would allow me to align the content to the NGSS, have a flexible format, and fit with the constructivist approach to learning; all of which the 5E lesson model encapsulates.

REFERENCES CITED

Andersen, P. (Producer). (2013-present). *Next Generation Science Standards Series* [Audio podcast]. Retrieved from http://www.bozemanscience.com

Atomsmith classroom of molecular exploration. (2010, January). Retrieved February 25, 2015, from http://www.bitwixt.com/jsite/atomsmithmoleculelab

Bybee, R. W. (2014). The BSCS 5E instructional model: Personal reflections and contemporary implications. *Science and Children*,*51*(8), 10-13. Retrieved from http://search.proquest.com/docview/1518522259?accountid=28148

Bybee, R.W., Taylor, J.A., et al. (2006). The BSCS 5E instructional model: Origins, effectiveness, and applications. (Unpublished professional paper). Office of Scientific
Education, National Institutes of Health, Colorado Springs, Colorado.

Duschl, R., Schweingruber, H., & Shouse, A. (2007). Taking science to school: Teaching science in grades K-8. Washington DC, National Academies Press.

Edgar, J. (2013). Mathematical modeling of chemical processes. University of Texas Austin. Retrieved April 17, 2016 from http://che.utexas.edu/course/che360/lecture_notes/ch2.doc

Grooms, J., Enderle, P., & Sampson, V. (2015). Coordinating scientific argumentation and the next generation science standards through argument driven inquiry. *Science Educator*, *24*(1), 45-50. Retrieved from http://search.proquest.com/docview/1698102742?accountid=28148

Hake, R. (1999). Analyzing change gain scores. Indiana University. Retrieved May 30, 2016 from: http://www.physics.indiana.edu/~sdi/AnalyzingChange-Gain.pdf

Kruse, B. (Photographer) (2015, May 16). Kayakers take to the water in Seattle to protest offshore drilling in the Arctic. onEarth: The Magazine of the Natural Resources Defense Council. Retrieved February 19, 2016, from http://www.onearth.org/earthwire/shell-protests-seattle-arctic-drilling

Lawson, A.E. (1995). *Science teaching and the development of thinking*. Belmont, CA: Wadsworth Publishing Company.

Moyer, R.H., & Everett, S.A. (2013, September). Everyday Engineering: Producing plastic…from milk? *Science Scope*, 80-86. Retrieved February 11, 2016, from http://static.nsta.org/files/ss1301_80.pdf

National Research Council. (2012). A *Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

National Research Council. (2006). *America's Lab Report: Investigations in High School Science.* Committee on High School Science Laboratories: Role and Vision. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

NGSS Lead States. (2013). *Next generation science standards: For States, By States*. Washington, D.C.: National Academies Press.

PowerSchool. (2014). Enrollment summary: scheduling/reporting ethnicity. Pearson Education, Inc. Retrieved February 26, 2016. Retrieved from https://pssecondary.lewistonschools.net/admin/reports/ethnicitybreakdown

Ruiz-Primo, M. A., Li, M., et al. (2010). Testing one premise of scientific inquiry in science classrooms: Examining students' scientific explanations and student learning. J. Res. Sci. Teach., 47: 583–608. doi: 10.1002/tea.20356

Russell, M. (n.d). Test of Scientific Literacy Skills. Retrieved November 13, 2015, from http://washburn.edu/academics/general-education-files/TOSLS.pdf

United States Census Bureau. (2015, March). Lewiston, Idaho population statistics. United States Department of Commerce. Retrieved April 13, 2015, Retrieved from http://quickfacts.census.gov/qfd/states/16/1646540.html

Wallace, R. (2005, May 16). Grading Rubric. Retrieved November 3, 2015, from https://labwrite.ncsu.edu/instructors/excelsheets.htm

Williams, K., Kurtek, K., & Sampson, V. (2011). The affective elements of science learning: A questionnaire to assess and improve student attitudes toward science. *The Science Teacher*, 1, 40-45.

APPENDICES

APPENDIX A

IRB EXEMPTION

INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects
FWA 00000165

MONTANA STATE UNIVERSITY

960 Technology Blvd. Room 127
c/o Immunology & Infectious Diseases
Montana State University
Bozeman, MT 59718
Telephone: 406-994-6783
FAX: 406-994-4303
E-mail: cherylj@montana.edu

Chair: Mark Quinn
406-994-5721
mquinn@montana.edu
Administrator:
Cheryl Johnson
406-994-6783
cherylj@montana.edu

MEMORANDUM

TO: Amy Chase and John Graves

FROM: Mark Quinn, Chair *Mark Quinn cj*

DATE: December 14, 2015

RE: *"The 5E Instructional Model for the Next Generation Classroom" [AC121415-EX]*

The above research, described in your submission of December 12, 2015, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

_X_ (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

_X_ (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

___ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

___ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

___ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

___ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

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

APPENDIX B

5E UNIT PLAN TEMPLATE

5E Organizer "Where do Plastics Come From?"

Learning Goals & Standards Addressed

HS-ESS3- Earth and Human Activity: Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

NGSS Science and Engineering focus: Engaging in Argument from Evidence: Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (economic, societal, environmental, ethical considerations).

7-E Description of Unit

Phase	Activity Sequence	Desired Outcome or Purpose
Engage	Demonstration in Puget Sound- students are given 3 minutes to make observations from the picture (without discussion), followed by a brief discussion on observations vs inferences. Students then classify their brainstorms. This is followed by a two minute period to formulate questions about the photograph. 	• Students will become interested in the content of the photograph. • Students will review the differences between an observation and inference. • Students will formulate questions to be explored in future lessons.
Explain	Video- Newsweek-Shell Offshore Drilling http://www.usatoday.com/story/money/business/2015/05/14/offshore-oil-rig/27303559/ Students will watch the video two times while creating a pro and con list of the debate surrounding the presence of oil rigs in Puget Sound.	• Students will be introduced to the shell oil rig debate in Seattle's Puget Sound in the Summer of 2015
Background	Students watch the following video while taking notes on the steps of making plastic from petroleum. http://www.totalrefiningchemicals.com/EN/aboutus/understand_petrochemicals/Pages/From-natural-gaz-to-Plastic.aspx Students will **model** the chemical reactions and steps involved in making plastic from ethane using **molecular model sets**	• To introduce students to the plastic-making process (from petroleum)
Explore	Polymerization: From Milk to Plastic (see attached) http://static.nsta.org/files/ss1301_80.pdf Students will apply concepts of making synthetic plastic from petroleum-based products to the making of casein, a natural plastic precipitated from a reaction of milk with an acid.	• Observe the chemical process of making a natural plastic • Manipulate a variable (example: amount of vinegar or

<table>
<tr><td></td><td></td><td>temperature or milk) to determine how this effects the amount of casein produced</td></tr>
<tr><td>Explain</td><td>Complete data tables and graphs of two different experiments to help determine the optimal casein yield.</td><td></td></tr>
<tr><td>Elaborate</td><td>Presentation to the CEO of Moo Incorporated:

Your group needs to create a digital poster to present to the CEO outlining your findings as the chemical engineers hired to increase casein production at Moo Incorporated. You may want to include:

1. Explanation of your experimentation
2. Findings of your experimentation
3. Optimal results in terms of industrial quantities (example: you would not use 15 mL in industry, calculate ratios instead)
4. Graphics
5. Further research/experimentation that may need to take place</td><td>• Analysis and Interpretation of Data
• Application of Experimental Findings</td></tr>
<tr><td>Evaluate</td><td>Unit Exam (Chemical Encounter)

Performance Rubric</td><td>• Apply knowledge gained through discussion and activities to a scenario</td></tr>
<tr><td>Extend</td><td>During the background section of this unit, we discussed how hydrogen gas was produced as a waste product in the process of making plastic from petroleum-based products. Recycling industrial waste could unlock great potential from an economic standpoint while also helping reduce environmental impact.

1. Write the two chemical reactions below that produced plastic from petroleum. Highlight the waste product in both reactions.

Throughout the rest of the unit, you discovered a chemical reaction that took place between milk and an acid which resulted in the coagulation of milk. You then separated the curds from the whey. The production of the casein produced an 80-90% waste! Your task is to research this waste product. What could it be used for, and how would you further develop the waste into a consumable product?

2. Start by completing a concept map with milk at the top. Your first division should be addition of acid…then list the two products, and go from there:
3. Research Response (2-4 paragraphs).</td><td></td></tr>
</table>

Chemical Reaction 5E Lesson Plan

Learning Goals & Standards Addressed

HS-PS1-2-Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

As an indicator of understanding, students should be able to…

Write complete balanced chemical equations. Predict products based on reactants given. Predict the solubility of compounds. Given an activity series, predict the replacement of elements in a single replacement reaction. Recognize qualitative signs of chemical reactions. Understand that chemical equations drive observations and experimentation.

Prior Knowledge

Students should have an understanding of prior to starting this unit • Formula Writing/Naming • Balancing Chemical Equations • Laboratory Practices and Safety Skills

7-E Description of Unit

Phase	Activity Sequence	Desired Outcome or Purpose
Elicit	**Starter:** State the law of conservation of matter/mass. Write the following chemical equation. Does it satisfy the law of conservation of matter/mass? Please explain your answer. **Starter:** List the diatomic molecules (give the name and formula). Why are these 7 molecules important when writing chemical equations?	Starters were given at the beginning of each day. They provided a platform to emphasize previously taught material. During this unit, the starters were utilized to emphasize material essential to the understanding, writing and balancing chemical equations. This is the first unit where several pieces of prior knowledge is synthesized *The first two starters are provided*

Engage	Demonstrations **"Golden Rain"** $Pb(NO_3)_{2(aq)} + 2KI_{(aq)} \rightarrow PbI_{2(ppt)} + 2KNO_{3(aq)}$ http://www.rsc.org/eic/2014/12/golden-rain-precipitation-demonstration **"Elephant Toothpaste"** $2H_2O_2 \xrightarrow{KI} 2H_2O + O_2$ http://www.chem.umn.edu/services/lecturedemo/info/Toothpaste.htm	• Golden Rain First day • Elephant Toothpaste, when decomposition reactions are introduced during the experiment *Demonstrations are presented as discrepant events*
Explore **Round 1**	Atomsmith Molecule Lab: Reactions Interactive Tutorial http://www.bitwixt.com/jsite/atomsmithmoleculelab	Introduce the 5 main types of chemical reactions through visualization
Explain **Round 1**	Chemical Reactions Classroom Notes: Nearpod	• Supplement Notes from Atomsmith Molecule Lab • Define components of chemical equations • Define 5 types of chemical reactions
Explore **Round 2**	Modified Chemical Reactions Lab- Written Chemical Equations and Predictions http://www.kwanga.net/chemnotes/chem-rxns-lab.pdf THE EXPLORE AND EXPLAIN COMPONENT ARE CYCLED THROUGH FOR EACH OF THE FIVE CHEMICAL REACTION TYPES. • Students complete equations and predictions for one section and get them checked off by the instructor. • This is immediately followed by performing the reaction in lab. • Steps are repeated for remaining reaction types.	• Introduced one section at a time • Emphasis is placed on the complete balanced chemical equation driving the prediction and what should be observed during experimentation. *Note: This is flipped from the traditional 5E model. The hands-on experience during this unit is used as the "Explain" component rather than the "Explore" component*

Explain **Round 2**	Modified Chemical Reactions Lab- Experimental Observations http://www.kwanga.net/chemnotes/chem-rxns-lab.pdf THE EXPLORE AND EXPLAIN COMPONENT ARE CYCLED THROUGH FOR EACH OF THE FIVE CHEMICAL REACTION TYPES. • Students complete equations and predictions for one section and get them checked off by the instructor. • This is immediately followed by performing the reaction in lab. Steps are repeated for remaining reaction types.	• Emphasis is placed on the complete balanced chemical equation driving the observations during experimentation. *Note: This is flipped from the traditional 5E model. The hands-on experience during this unit is used as the "Explain" component rather than the "Explore" component*
Elaborate	Practice at Writing Chemical Equations (see attached)	*Given as homework throughout the unit* *Graded and reviewed before the unit test*
Evaluate	Chemical Reactions Laboratory Performance Rubric Chemical Reactions Unit Exam	
Extend	Students are given a task to write the complete balanced chemical equation for the reaction between aluminum and iron (III) oxide. They are then asked to research and the chemical reaction.	This activity provides background for the next lesson

“Our" Thermite Reaction

Accounting for Copper in a chemical Reaction

Duration: 2- 85 Minute Blocks   Start Date: 3/29/2016   Finish Date:3/31/2016

Subject(s): General Chemistry   Grade Level: 11

Author: Amy Chase   Teaching Team: Amy Chase, Nancy Johnston

Unit Focus

NGSS Standards Addressed

HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

HS-PS1-2: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

S & E Practices: construct explanations and design solutions, Use mathematical and computational thinking, analyze and interpreting data,

Learning Outcome: Mathematically describe how matter is conserved in a chemical reaction.

Prior Learnings / Connections: identifying types of chemical reactions, writing balanced chemical equations, molar mass, laboratory safety, measuring skills

Comments/Reminders

This lesson serves as a link between the chemical reaction and stoichiometry units.

Phase	Activity Sequence	Desired Outcome or Purpose
Elicit **(prior knowledge)**	Students should have a prior knowledge in the following areas for this lesson: identifying types of chemical reactions, writing balanced chemical equations, molar mass, laboratory safety, measuring skills	
Engage	**On Screen Chemistry- Breaking Bad (III): Thermite Break-in** http://www.rsc.org/images/Mole-March2012-On-screen-chemistry-breaking-bad_tcm18-233915.pdf	• Students will be able to write the complete chemical reaction for “thermite”. • Describe signs of a chemical reaction • Classify thermite as an exothermic, single replacement, redox reaction
Explore	**Experiment:** Students perform a single replacement reaction between zinc and copper (II) oxide. $Zn + CuO \rightarrow ZnO + Cu$ • Students measure the amount of zinc and copper oxide utilized in the reaction prior to ignition.	• Implement the activity series to predict single replacement reactions • Describe signs of a chemical reaction • Illustrate how chemical reactions satisfy the law of conservation of matter

Explain	**Stoichiometry:** Explain/demonstrate how a balanced chemical equation can be utilized to derive the amount of substances that are reacted and produced in a chemical reaction.	Students will calculate the amount of copper produced from their chemical reaction.
Elaborate	**Extracting Cu from the solid products-** Zinc Oxide Reacts with Hydrochloric acid. Design an experiment that will extract the pure copper from the products in the “Our” Thermite Reaction. How much copper was produced? (**actual yield**) Based on your calculations, how much copper should have been produced?	Predict the outcome of a double replacement reaction. Describe signs of a chemical reaction Illustrate how chemical reactions satisfy the law of conservation of matter
Evaluate	Write a **paragraph response** that answers this question: Does this experiment prove or violate the law of conservation of mass/matter? Support your claim with evidence collected from the experiment.	Illustrate how chemical reactions satisfy the law of conservation of matter
Extend	**Calculate Percent Yield** $\text{percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$ actual yield =from an experiment Theoretical yield= from stoichiometric calculations **Analysis of Class Data:** Given the class data, what should be the minimum percent yield accepted?	Analyzing and Interpreting Data What should be an acceptable percent yield? Discussion of statistical analysis

7E Organizer: Airbag Design Project

Learning Goals & Standards Addressed (NGSS)

HS-PS1-6→ Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium HS-PS1-7 → Use mathematical representation to support the claim that atoms, and therefore mass, are conserved during a chemical reaction HS-PS3-3 → Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. HS-ETS1-3 → Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. HS-ETS1-2 → Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

As an indicator of understanding, students should be able to…

Design a model air bag system in a prototype car using a reaction of sodium bicarbonate and acetic acid that will protect a raw egg in a simulated crash test.

7-E Description of Unit

Phase	Activity Sequence	Desired Outcome or Purpose
Engage **Round 1**	"How does an Airbag work?" Student perspective: I've wondered about that. Watch, *Crash Test Dummies, Seatbelts, Momentum and Airbags* https://www.youtube.com/watch?v=y118jLg20i0 Introduce project by discussing final product and breaking into individual components.	• Introduce Project • Students will have a clear path and purpose for the overall project and a general understanding of the individual components which will be described in more detail further into the project.
Explore **Round 1**	Students will create a background video to provide background information on an airbag. Videos should include: • History (who, what, when, where, why it was invented) • How an airbag works (with a diagram) • The main chemical reaction inside an airbag (written out with explanation) • Interesting facts	• Students will gain an understanding of how an airbag works. • Students will be able to apply this understanding further into the project.

Explain **Round 1**	Teacher guided lecture on the decomposition of sodium azide including subreactions that neutralize the product, sodium.	• Emphasize the real chemical reactions that takes place inside an air bag before moving to the simulated reaction for the project.
Elicit **(Round 2)**	After introducing the prototype airbag chemical reactants (vinegar and baking soda), students will write a complete balanced chemical equation.	• Practice using skills obtained from the chemical reaction unit to write, predict products, and balance chemical reactions.
Explain/Explore **(Round 2)**	Students use Atomsmith Software to explore the two step chemical reaction between vinegar and baking soda. Class discussion occurs during the simulation.	• Help students visualize how this reaction takes place in two steps with the decomposition of carbonic acid.
Explore **Round 2**	Students are given the task to find the <u>volume</u> of their sandwich bag (student-guided). They were also given a choice between two bags: • 1- normal size sandwich bag <u>or</u> • 2- snack size bags	• Students utilize scale, portion to determine maximum volume of their sandwich bag. • Students determine that variance exists between like bags
Explain **Round 2**	From the volume of their simulated airbag, students are given a teacher-guided lesson on how to calculate the amount of vinegar and baking soda using stoichiometry.	• Students will be able to apply principles of stoichiometry to their own calculations, with a little guidance from the teacher.
Elaborate **(Round 2)**	When students make the second video section, they transfer their learning through their own explanations. • 2nd video section – Explain the Prototype air bag including: the chemical reaction, design of the airbag, trials they conducted and an explanation of the stoichiometric calculations.	• Students will be able to explain their calculations on video using props.
Explore **(Round 3)**	Students create a prototype automobile that will hold a crash test dummy (raw egg) that will withstand a 3 story fall. Design constraints include: • Once airbag is deployed, car must be launched within 2 minutes • All materials must be similar in structure and function to the material they are simulating (example: you <u>cannot</u> make a seat out of bubble wrap!)	• Students will apply concepts of engineering and design to create a prototype car. • Students will create a successful prototype where an egg will 'survive' a three story fall.

	• The simulated car should resemble a car! You need to account for each component. • All other safety features in a car are fair game! However, you can only have the designated amount of airbags. • The egg must be raw, and provided by the student.	
Elaborate **(Round 3)**	When students make the third video section, they transfer their learning through their own explanations. 2rd video section – Explain the Prototype car design including: size, placement of airbag, requirements of other safety features, time limit, etc. (see above)	• Students will be able to explain how they designed and built their car to be successful.
Explore **(Round 3)**	Prototype Launch Students launch their model cars off a three story building (out window or roof with safety ledge) Film section 3: Filming of launch	Test and evaluate designs
Explain **(Round 3)**	Students discuss the design constraints and discussion for improvements in design of prototype. (film section 4)	Design solutions using evidence
Evaluate	Students present final spliced film to another group or class and complete the project rubric.	Students will learn from each other's designs and explanations. *Evaluative rubric should be handed out after explanations of chemical reactions.*

APPENDIX C

SCIENCE LITERACY PRE AND POST ASSESSMENT

Science Literacy

DO NOT MARK ON THE EXAM!

The test comprises 20 questions. A maximum time allowance of 30 minutes will be given. Calculators are NOT permitted, and no outside sources may be used. Note: This test is intended to record your current level of scientific reasoning and literacy skills and does not reflect natural science ability or content skill level.

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1. Which of the following is a valid scientific argument?

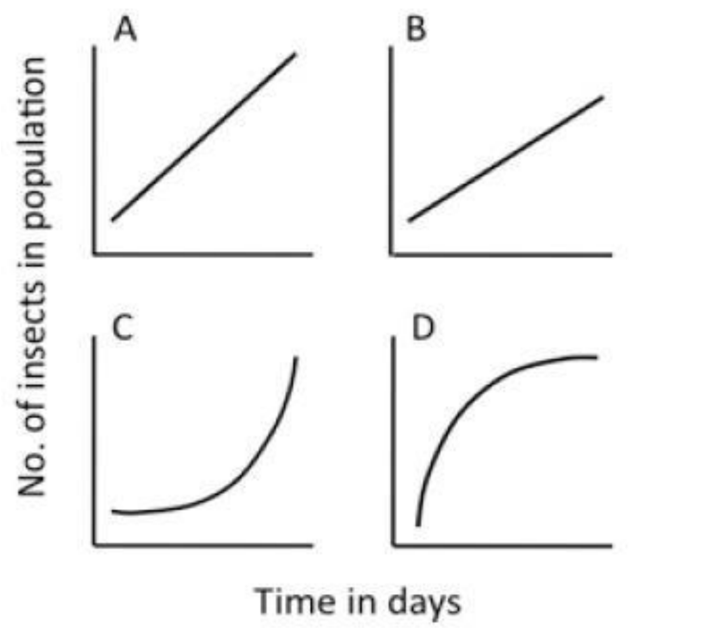
   A. Measurements of sea level on the Gulf Coast taken this year are lower than normal; the average monthly measurements were almost 0.1 cm lower than normal in some areas. These facts prove that sea level rise is not a problem.
   B. A strain of mice was genetically engineered to lack a certain gene, and the mice were unable to reproduce. Introduction of the gene back into the mutant mice restored their ability to reproduce. These facts indicate that the gene is essential for mouse reproduction.
   C. A poll revealed that 34% of Americans believe that dinosaurs and early humans co-existed because fossil footprints of each species were found in the same location. This widespread belief is appropriate evidence to support the claim that humans did not evolve from ape ancestors.
   D. This winter, the northeastern US received record amounts of snowfall, and the average monthly temperatures were more than 2°F lower than normal in some areas. These facts indicate that climate change is occurring

2. A study about life expectancy was conducted using a random sample of 1,000 participants from the United States. In this sample, the average life expectancy was 80.1 years for females and 74.9 years for males. What is one way that you can **<u>increase your certainty</u>** that women truly live longer than men in the United States' general population?

   A. Subtract the average male life expectancy from the average female expectancy. If the value is positive, females live longer.
   B. Conduct a statistical analysis to determine if females live significantly longer than males.
   C. Graph the mean (average) life expectancy values of females and males and visually analyze the data.
   D. There is no way to increase your certainty that there is a difference between sexes.

3. While growing vegetables in your backyard, you noticed a particular kind of insect eating your plants. You took a rough count (see data below) of the insect population over time. Which graph shows the **best** representation of your data?

Time	Insect Population
(days)	(number)
2	7
4	16
8	60
10	123



A. Graph A
B. Graph B
C. Graph C
D. Graph D

4. Which of the following research studies is <u>**least likely**</u> to contain a confounding factor (variable that provides an alternative explanation for results) in its design?

A. Researchers randomly assign participants to experimental and control groups. Females make up 35% of the experimental group and 75% of the control group.
B. To explore trends in the spiritual/religious beliefs of students attending U.S. universities, researchers survey a random selection of 500 freshmen at a small private university in the South.
C. To evaluate the effect of a new diet program, researchers compare weight loss between participants randomly assigned to treatment (diet) and control (no diet) groups, while controlling for average daily exercise and pre-diet weight.

D. Researchers tested the effectiveness of a new tree fertilizer on 10,000 saplings. Saplings in the control group (no fertilizer) were tested in the fall, whereas the treatment group (fertilizer) were tested the following spring.

5. The **<u>most important</u>** factor influencing you to categorize a research article as trustworthy science is:

A. the presence of data or graphs
B. the article was evaluated by unbiased third-party experts
C. the reputation of the researchers
D. the publisher of the article

6. Creators of the Shake Weight, a moving dumbbell, claim that their product can produce "incredible strength!" Which of the additional information below would provide the **<u>strongest evidence</u>** supporting the effectiveness of the Shake Weight for increasing muscle strength?

A. Survey data indicates that on average, users of the Shake Weight report working out with the product 6 days per week, whereas users of standard dumbbells report working out 3 days per week.
B. Compared to a resting state, users of the Shake Weight had a 300% increase in blood flow to their muscles when using the product.
C. Survey data indicates that users of the Shake Weight reported significantly greater muscle tone compared to users of standard dumbbells.
D. Compared to users of standard dumbbells, users of the Shake Weight were able to lift weights that were significantly heavier at the end of an 8-week trial.

7. Which of the following actions is a valid scientific course of action?

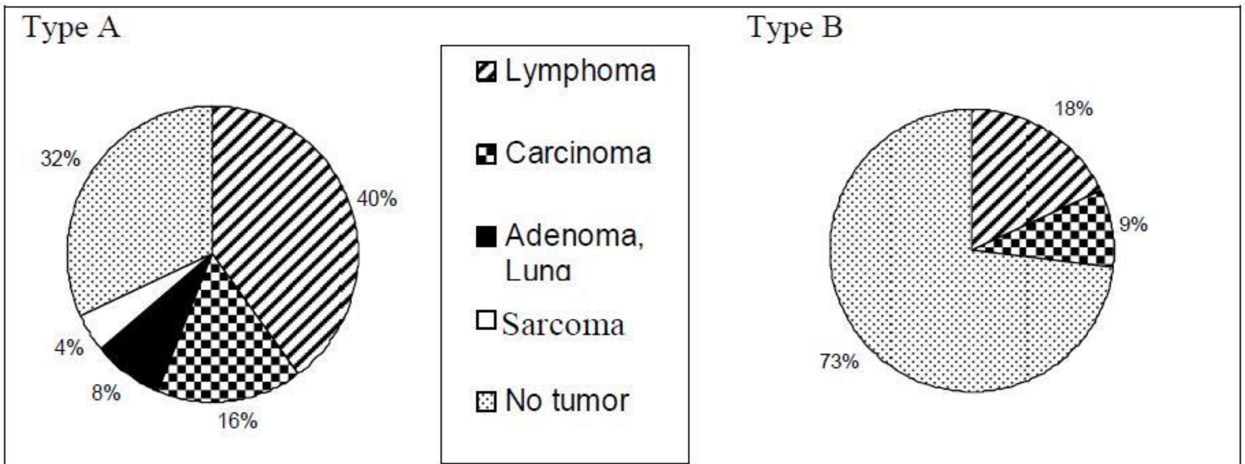
A. A scientific journal rejects a study because the results provide evidence against a widely accepted model.
B. The scientific journal, Science, retracts a published article after discovering that the researcher misrepresented the data.
C. A researcher distributes free samples of a new drug that she is developing to patients in need.
D. A senior scientist encourages his graduate student to publish a study containing ground-breaking findings that cannot be verified.

8. A researcher hypothesizes that immunizations containing traces of mercury **<u>do not</u>** cause autism in children. Which of the following data provides the **<u>strongest</u>** test of this hypothesis?

A. a count of the number of children who were immunized and have autism
B. yearly screening data on autism symptoms for immunized and non-immunized children from birth to age 12

C. mean (average) rate of autism for children born in the United States
D. mean (average) blood mercury concentration in children with autism

9. Which of the following is the **best** interpretation of the graph below?



Tumors found in type A and type B mice. Pie chart depicts relative incidence of tumors. Numbers outside each slice denote the percentage of specific tumor type.

A. Type "A" mice with Lymphoma were more common than type "A" mice without tumors.
B. Type "B" mice were more likely to have tumors than type "A" mice.
C. Lymphoma was equally common among type "A" and type "B" mice.
D. Carcinoma was less common than Lymphoma only in type "B" mice.

10. A gene test shows promising results in providing early detection for colon cancer. However, 5% of all test results are falsely positive; that is, results indicate that cancer is present when the patient is, in fact, cancer-free. Given this false positive rate, how many people out of 10,000 would have a false positive result and be alarmed unnecessarily?

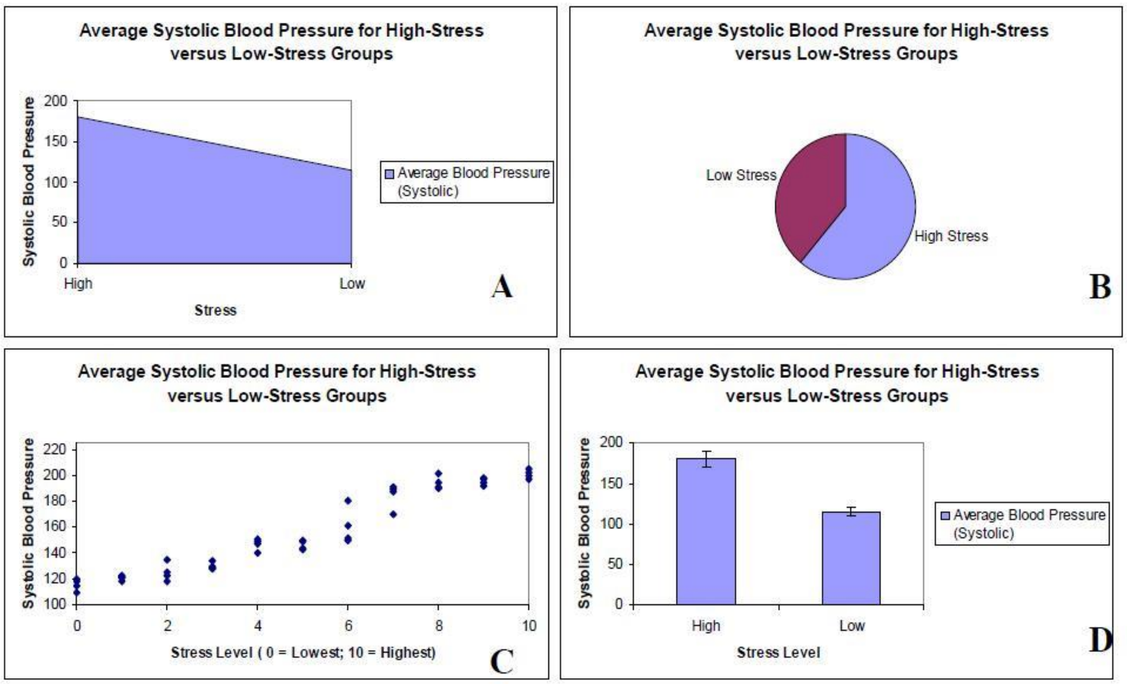
A. 5
B. 35
C. 50
D. 500

11. Two studies estimate the mean caffeine content of an energy drink. Each study uses the same test on a random sample of the energy drink. Study 1 uses 25 bottles, and study 2 uses 100 bottles. Which statement is true?

A. The estimate of the actual mean caffeine content from each study will be <u>equally uncertain</u>.
B. The uncertainty in the estimate of the actual mean caffeine content will be <u>smaller</u> in study 1 than in study 2.

C. The uncertainty in the estimate of the actual mean caffeine content will be <u>larger</u> in study 1 than in study 2.
D. None of the above

12. Researchers found that chronically stressed individuals have significantly higher blood pressure compared to individuals with little stress. Which graph would be most appropriate for displaying the mean (average) blood pressure scores for high-stress and low-stress groups of people?

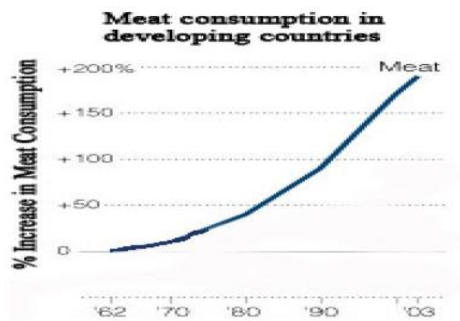


A. Figure A
B. Figure B
C. Figure C
D. Figure D

13. Your doctor prescribed you a drug that is brand new. The drug has some significant side effects, so you do some research to determine the effectiveness of the new drug compared to similar drugs on the market. Which of the following sources would provide the **most accurate** information?

A. the drug manufacturer's pamphlet/website
B. a special feature about the drug on the nightly news
C. a research study conducted by outside researchers
D. information from a trusted friend who has been taking the drug for six months

14. Which of the following is the **most accurate** conclusion you can make from the data in this graph?



A. The largest increase in meat consumption has occurred in the past 20 years.
B. Meat consumption has increased at a constant rate over the past 40 years.
C. Meat consumption doubles in developing countries every 20 years.
D. Meat consumption increases by 50% every 10 years.

15. Background: Your interest is provoked by a story about human pheromones on the news. A Google search leads you to the following website:

For this website (Eros Foundation), which of the following characteristics is **most important** in your confidence that the resource is accurate or not.

(See following page for website)

A. The resource may not be accurate, because appropriate references are not provided.
B. The resource may not be accurate, because the purpose of the site is to advertise a product.
C. The resource is likely accurate, because appropriate references are provided.
D. The resource is likely accurate, because the website's author is reputable.


EROS FOUNDATION
Special Sale
Pheromone 10.13 increase romance in your life; 1.6 oz. bottle normally $98.50. (25% off for first time customers.)
Order Now
EROS HOME
EROS SCIENCE
PHEROMONE DISCOVERY
BOOKS AND PRODUCTS
MEDIA ARTICLES
CONTACT US
VIDEO LINKS
Shortcuts
Click here
To Order From Eros
Privacy Protection
Share
Explore the Site
Eros Home
Top Stories
Dr. Baxter's Articles
Discoveries
Baxter in the Scientific Community
Other Health Research
Published Scientific Articles
EROS PHEROMONE 10X FOR MEN
EROS PHEROMONE 10X FOR WOMEN
Fragrance additives to enhance sex-appeal
Welcome to the Eros Foundation
a biomedical research facility
Founded in 1995 by Dr. Millicent Baxter President,
Biologist and co-discoverer of pheromones in humans
and author of:
Hormones and your Health: The Smart Woman's Guide to Hormonal and Alternative Therapies for Menopause
To Order Click Here
Dr. Millicent Baxter, B.S. in Psychology cum laude from Uttica College in 1981, earned her Ph.D. in Biology from Duke University in 1987 followed by postdoctoral work in behavioral endocrinology at Stanford University. In 1995 she co-founded the Women's Wellness Program at the Hospital of State University of New York, Buffalo. She has published over 35 scientific papers, is co-inventor on 5 patents and author of eight books on women's health.
Eros Science...
ntific cles by Dr. Baxter
Discoveries and Bibliography
In the Scientific Community
Scholarly Peer-Reviewed Published Eros Science
In December 2010, the International Menopause Society journal published Dr. Baxter's invited review of a published paper showing breast cancer seemed to decrease. The 2002 WHI study and subsequent media caused women to stop using hormone replacement therapy.
Baxter, M, McColl NL, Leiberman, E, Calabrese-Stone E, (2000) Sexual response in women, Obstetrics & Gynecology 95:4(Supplement) April 2000, 19S.
Baxter M, McColl NL, Leiberman, E (1998) Pheromonal Influences on Sociosexual Behavior. Archives of Sexual Behavior 24:1-13
Baxter M, Calabrese-Stone E (1998) Women After 40 Years of Age: The Role of Sex Hormones and Pheromones. Disease-A-Month, 44:423-546
Breast Cancer in Postmenopausal Women: What is the Real Risk? Dr. Baxter's oral presentation and abstract was accepted for the 65th annual meeting of the American Society of Reproductive Medicine (ASRM) October 2009
Our Products are shipped in Plain Packages to Protect your Privacy

Background for questions 16-18: Use the excerpt below (modified from a recent news report on MSNBC.com) for the next few questions.

"A recent study, following more than 2,500 New Yorkers for 9+ years, found that people who drank diet soda every day had a 61% higher risk of vascular events, including stroke and heart attack, compared to those who avoided diet drinks. For this study, Hannah Gardner's research team randomly surveyed 2,564 New Yorkers about their eating behaviors, exercise habits, as well as cigarette and alcohol consumption. Participants were also given physical check-ups, including blood pressure measurements and blood tests for cholesterol and other factors that might affect the risk for heart attack and stroke. The increased likelihood of vascular events remained even after Gardener and her colleagues accounted for risk factors, such as smoking, high blood pressure and high cholesterol levels. The researchers found no increased risk among people who drank regular soda."

16. The findings of this study suggest that consuming diet soda might lead to increased risk for heart attacks and strokes. From the statements below, identify **additional evidence that supports** this claim:

A. Findings from an epidemiological study suggest that NYC residents are 6.8 times more likely to die of vascular-related diseases compared to people living in other U.S. cities.
B. Results from an experimental study demonstrated that individuals randomly assigned to consume one diet soda each day were twice as likely to have a stroke compared to those assigned to drink one regular soda each day.
C. Animal studies suggest a link between vascular disease and consumption of caramel-containing products (ingredient that gives sodas their dark color).
D. Survey results indicate that people who drink one or more diet soda each day smoke more frequently than people who drink no diet soda, leading to increases in vascular events.

17. The excerpt above comes from what type of source of information?

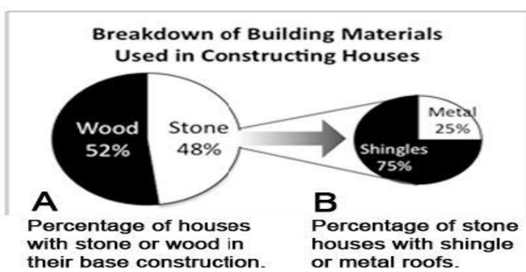
A. Primary (Research studies performed, written and then submitted for peer-review to a scientific journal.)
B. Secondary (Reviews of several research studies written up as a summary article with references that are submitted to a scientific journal.)
C. Tertiary (Media reports, encyclopedia entries or documents published by government agencies.)
D. None of the above

18. The lead researcher was quoted as saying, "I think diet soda drinkers need to stay tuned, but I don't think that anyone should change their behaviors quite yet." Why didn't she warn people to stop drinking diet soda right away?

A. The results should be replicated with a sample more representative of the U.S. population.
B. There may be significant confounds present (alternative explanations for the relationship between diet sodas and vascular disease).
C. Subjects were not randomly assigned to treatment and control groups.
D. All of the above

19. Background: Energy efficiency of houses depends on the construction materials used and how they are suited to different climates. Data was collected about the types of building materials used in house construction (results shown below). Stone houses are more energy efficient, but to determine if that efficiency depends on roof style, data was also collected on the percentage of stone houses that had either shingles or a metal roof.

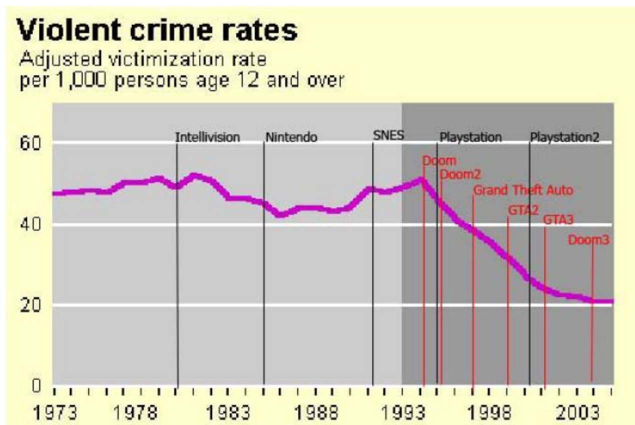
What proportion of houses were constructed of a stone base with a shingled roof?



A. 25%
B. 36%
C. 48%
D. Cannot be calculated without knowing the original number of survey participants.

20. Background: A videogame enthusiast argued that playing violent video games (e.g., Doom, Grand Theft Auto) does not cause increases in violent crimes as critics often claim. To support his argument, he presents the graph below. He points out that the rate of violent crimes has decreased dramatically, beginning around the time the first “moderately violent” video game, Doom, was introduced.

Considering the information presented in this graph, what is the **most critical** flaw in the blogger’s argument?



A. Violent crime rates appear to increase slightly after the introduction of the Intellivision and SNES game systems.
B. The graph does not show violent crime rates for children under the age of 12, so results are biased.
C. The decreasing trend in violent crime rates may be caused by something other than violent video games
D. The graph only shows data up to 2003. More current data are needed.

APPENDIX D

UNIT GRADING RUBRICS

Pre Treatment *Performance Task: Experimental Scoring Rubric and the S&E Practices*

EVALUATION: Lab Report ______ Writer: ______

Section Points			Poor 0	0.25	0.5	0.75	Excellent 1	Section Scores
8		**Chemical Reaction**						0.00
	8	A balanced chemical equation is provided for all reactions in the experiment						0.00
2		**Title**						0.00
	2	Describes lab content concisely, adequately, appropriately						0.00
15		**Scientific Claim/Hypothesis**						0.00
	8	Successfully establishes the scientific concept of the lab						0.00
	7	States hypothesis and provides logical reasoning for it						0.00
10		**Methods**						0.00
	10	Gives enough details to allow for replication of procedure						0.00
12		**Data**						0.00
	3	Presents visuals clearly and accurately in tables and graphs						0.00
	3	Presents sufficient qualitative data						0.00
	3	Presents sufficient quantitative data						0.00
	3	Unknown sample data is provided						0.00
20		**Analysis/Evidence**						0.00
	4	Appropriate calculations are addressed						0.00
	4	Qualitative results are accurately discussed						0.00
	4	Quantitative results are accurately discussed						0.00
	4	Possible experimental error is addressed						0.00
	4	Unknown samples are identified with evidence						0.00
13		**Conclusion**						0.00
	3	Restates the purpose of the experiment						0.00
	10	Convincingly describes what has been learned in the lab						0.00
4		**References**						0.00
	2	All appropriate sources in the report are listed						0.00
	2	Citations and references adhere to proper format						0.00
6		**Presentation**						0.00
	2	Format of tables and figures is correct						0.00
	2	Report is written in scientific style: clear and to the point						0.00
	2	Grammar and spelling are correct						0.00
10		**Overall aims of the report:** *the student...*						0.00
	2	Has successfully learned what the lab is designed to teach						0.00
	2	Demonstrates clear and thoughtful scientific inquiry						0.00
	2	Accurately measures and analyzes data for lab findings						0.00
	2	Demonstrated proper laboratory technique						0.00
	2	Demonstrated proper safety protocol						0.00
100							**Points Earned**	**0.00**
							Total Possible Points	100
							Percentage	**0%**

Wallace, R. (2005, May 16). Grading Rubric. Retrieved November 3, 2015, from https://labwrite.ncsu.edu/inst

Petroleum to Plastics Rubric

Casein Production from Milk

Grading Rubric

Engage

	Included, with Sufficient Detail (2 Points)	**Included, but lacking Detail (1 Point)**	**Not Included (0 Points)**
Observations- Brainstorm			
Observations classified as observations or inferences			
Questions- Brainstorm			
Exit Ticket- Why was the picture ironic?			

Category Total ______/8

(Included in classwork, not lab grade)

Explore

	Correctly Included (1 Point)	Not Included (0 Points)
Question		
Independent Variable		
Dependent Variable		
Controlled Variable		
Data		

	Correctly Included (1 Point)	Not Included (0 Points)
Question		
Independent Variable		

Dependent Variable

Controlled Variable

Data

Category Total ______/10

Explain

Casein Production with Varying Volumes of Vinegar

	Correctly Included	Partially Included	Not Included
1. Mass of Casein	(2 pts)	(1 pt)	
2. Graph- Included	(4 pts)	(3-1)	
3. As the vinegar increased, what happened to the volume?	(2)- Increased- answer is supported by data from lab	(1)- Answer is partial.	
4. Graph helping a chemical engineer	(2)- Answer is supported by data **and** addresses economics	(1) Answer is supported by data	

Casein Production (Open-Ended Design)

	Correctly Included	Partially Included	Not Included
1. Mass of Casein	(2 pts)	(1 pt)	
2. Graph- Included	(4 pts)	(3-1)	
3. As the vinegar increased, what happened to the volume?	(2)- Increased- answer is supported by data from lab	(1)- Answer is partial.	
4. Graph helping a chemical engineer	(2)- Answer is supported by data **and** addresses economics	(1) Answer is supported by data	

Category Total ______/20

Elaborate

Proposal Based on Experiment- 5pts

Number Changed to Fit Manufacturing Needs- 5 pts

CEO Presentation-Uploaded to Google Classroom- 5pts

Category Total ______/15

Extend

	Included (1pt)	Partially Included	Not Included (0 pts)
Question 1- Chemical RXN			
(1st step)			
Question 1- Chemical RXN- (2nd Step)			
Waste Product Highlighted			
Question 2- Concept Map			
	Included (3pt)	Partially Included (2-1)	Not Included (0 pts)
Question 3- Description of Whey			
Question 3- How to Process			
Question 3- Uses of Whey			
Grammar/ Sentence Mechanics	(2pts)	(1pt)	(0)

Category Total ______/15

TOTAL ____________/60 points

Investigating Types of Chemical Reactions Laboratory Rubric

Maximum

Score: 56

Pre-Lab **32 pts total**

Criteria:

- Allow **16 points** for chemical equations. (1 points each)
  - states of matter must be present (1/2 point each)
  - must be balanced (1/2 point each)
- Allow **16 points** for predictions (1 point each)
  - Prediction is based on the information from the chemical equation (1/2 point)
  - Prediction is based on the information from the laboratory procedure (1/2 point)

  -Example: A precipitate, PbI_2 will form.

Experiment **16 pts**
total

- Allow 16 points (1 points each) for written observations
  - Observations must be written **AFTER** equation and prediction is made
  - Observations must be verified by equation (1/2 point)

  -Example: A popping noise was witnessed when a lit stick was introduced to the test tube. This verifies the production of hydrogen gas in the experiment.

Logistics **8 pts**
total

- Allow **8 points** for <u>13</u> out of 16 <u>stamps/initials</u> from teacher.
  - Each equation and prediction was completed prior to lab
  - Note: 3 equations were not performed as a laboratory component and may not be stamped

Airbag Design Project

Category	3	2	1	0	STUDENT SCORE
Identification of the Problem	Problem to be solved has been clearly stated			Problem [illegible] s	____ /3
Evidence of Research and understanding airbag design **HISTORY**	History of the airbag is provided including important dates, people, etc.			provided	____ /3
Evidence of Research and understanding airbag design **DESIGN** **SPECIFICATIONS**	Discussion of airbag engineering and design is provided including mechanisms for operation	Discussion of airbag engineering and design is provided but missing a clear understanding of process	Discussion of airbag engineering and design is provided but lacking major components	Missing /Incomplete	____ /3
Diagram Provided, with description of components	A visual is provided thoroughly explaining the components of an airbag		Yes = 3 Incomplete =1 No =0		____ /3
Evidence of Research and understanding	Demonstrates clear understanding of the chemistry	Understanding of chemistry is missing a concept ____	Understanding of chemistry is missing several componen	Missing /Incomplete	

airbag design **CHEMISTRY**	(chemical reaction)	____________ ____________ ____________ ____	ts __________ _______ __________ _______ __________ _______		____ **/3**
Chemical Equation for airbag given **$2NaN_{3(s)} \rightarrow 2Na_{(s)} + 2N2_{(g)}$**		Yes = 3 Incorrect =1 No =0			____ **/3**
Prototype Design-Intro Explanation	Process of prototype for the project is explained in terms of testing sandwich bag 'airbag' in a crash test with an egg as the 'dummy' while dropping it from a height of 3 stories.		Yes = 2 No =0		____ **/2**
Prototype Equation **$NaHCO_3 + HC_2H_3O_2 \rightarrow NaC_2H_3O_2^{-} + CO_{2\,(g)} + H_2O$**			Yes = 3 Incorrect =1 No =0		____ **/3**
Experiment: Data/ Observations/ Results	Evidence of separate trials with revisions conducted each time is documented. Data is well organized and contains proper labels.	Documentation is missing one requirement. ____________ ____________ ____________ ____________ ____________ ____________ ____________	Documentation is missing two to 3 requirements. __________ __________ __________ __________ _ __________ ___	Missing /Incomplete	____ **/3**

Calculations	Stoichiometric calculation using dimensional analysis was provided for the $NaHCO_3$/ CO_2 relationship that resulted in the optimal amount of gas (either in mL of CO_2 of CO_2)		Correct = 6 Missing labels/sig figs =5 Incorrect calculation =3 Set-up incorrectly = 2 No work shown or no answer =0		___ /6
Airbag Prototype Design SPECIFI-CATIONS	All specifications were met in prototype design including: size, placement of airbag, requirements of other safety features, time limit, etc.		One to two specifications were not taken into consideration	Three or more specifications not taken into consideration	___ /3
Airbag Prototype Visual/explanation	A visual is provided thoroughly explaining the prototype components		Provided and Explained = 4 Provided, not thoroughly explained =3 Provided, not explained =2 Not provided = 0		___ /4
Conclusion DESIGN	Explains: The results of their design, including design strengths and flaws	Missing one component of the design requirements of explanation, strength and weaknesses	Missing more than one component of the design requirements of explanation, strength and	Missing /Incomplete	___ /3

			weaknesses		
Conclusion SUGGESTIONS FOR IMPROVEMENT	At least three suggestions for improvement are provided	Two suggestions for improvement are provided	One suggestion for improvement is provided	Missing /Incomplete	____ **/3**
Conclusion Chemistry	A thorough explanation of the chemistry learned in this project is provided including: a balanced chemical equation with an explanation of how the chemical equation was used to determine the amount of materials needed.		Provided and Explained = 5 Provided, not thoroughly explained =3-4 Provided, not explained =1-2 Not provided = 0		____ **/5**
Punctuality	Airbag design and report/video submitted on (soft) due date	Airbag design and report/video submitted on (hard) due date		Not submitted on time	____ **/3**

TOTAL ___________/53

APPENDIX E

RUBRIC CORRELATION TO

SCIENCE AND ENGINEERING PRACTICES

Pre Treatment Rubric- Breakdown of categories related to Science and Engineering Practices

Rubric Section	S&E Practice
Chemical Reaction	Developing and Using Models
Title, References, Presentation	Obtaining, Evaluating and Communicating Information
Scientific Claim/Hypothesis	Asking Questions and Defining Problems
Methods	Planning and Carrying out Investigations
Data	Analyzing and Interpreting Data
Analysis/Evidence	Analyzing and Interpreting Data
Conclusion	Constructing Explanations and Designing Solutions
Overall Aims of the Report	Planning and Carrying out Investigations
	Constructing Explanations and Designing Solutions

Petroleum to Plastics 5E Rubric Correlated to Science and Engineering Practices

Engage	Questions	Asking Questions
	Exit ticket	Engage in Argument From Evidence
Explore	Defining Variables	Planning and Carrying Out Investigations
	Collecting Data	Planning and Carrying Out Investigations
Explain	Graphing	Analyzing and Interpreting Data
	Volume of Casein Produced	Analyzing and Interpreting Data
	How Would an Engineer Use this Data?	Designing a Solution
Elaborate	CEO Presentation	Engage in Argument from Evidence
	CEO Presentation	Obtaining, Evaluating, and Communicating Information
Extend	Chemical RXN	Developing and Using Models
Extend	Use of Waste Product	Designing Solutions

Airbag Project 5E Rubric Correlated to Science and Engineering Practices

Airbag Rubric Component	Science and Engineering Practice Correlation
Explanation of Project	Defining Problems
Prototype Design and Explanation	Developing and Using Models
Modifications to Design	Designing a Solution
Stoichiometric Calculations to fill Simulated Airbag	Using Mathematics and Computational Thinking
Airbag Simulation (Sandwich Bag)	Planning and Carrying Out Investigations

APPENDIX F

SCIENCE AND ENGINEERING PRACTICES LESSON QUESTIONARE

Science and Engineering Practices Unit Survey

Please answer all questions as honestly as possible. This survey will not be graded. Your participation in this survey is entirely voluntary and no penalty will be given if you do not participate.

* 1. Please provide your name so I can track your responses throughout the semester. **I will not use your name in my research.**

2. On a scale of 1(poor) to 5 (excellent), rate your confidence level for each of the Science and Engineering Practices.

	1 (poor, I don't feel confident at all)	2 (below average, I get some of it but not enough to do well on a test)	3 (average, I could perform these skills with some help)	4 (above average, I can perform these skills by myself	5 (excellent, I could be a peer tutor and explain it to others)
Asking Questions and Defining Problems	○	○	○	○	○
Developing and Using Models	○	○	○	○	○
Planning and Carrying Out Investigations	○	○	○	○	○
Analyzing and Interpreting Data	○	○	○	○	○
Using Mathematics and Computational Thinking	○	○	○	○	○
Constructing Explanations and Designing Solutions	○	○	○	○	○
Engaging in Argumentation from Evidence	○	○	○	○	○
Obtaining, Evaluating, & Communicating Information	○	○	○	○	○

APPENDIX G

ELEMENTS OF SCIENCE LEARNING LIKERT SURVEY

Participation in this survey is voluntary and participation or non-participation will not affect a student's grade in any way.

Williams, K., Kurtek, K., & Sampson, V. (2011). The affective elements of science learning: A questionnaire to assess and improve student attitudes toward science. The Science Teacher, 1, 40-45.

1. Please State Your Name: This will be used for statistical purposes only, and will not appear in final documentation.

2. Select one choice for each item

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I can succeed in science.	○	○	○	○	○
I am confident that I understand science.	○	○	○	○	○
I can solve complex problems in science.	○	○	○	○	○
Science is too hard.	○	○	○	○	○
I can interpret data tables and graphs in science.	○	○	○	○	○
I can create scientific explanations using evidence.	○	○	○	○	○
I can understand new ideas quickly when they are introduced to me in the science classroom.	○	○	○	○	○
I understand scientific theories, laws and concepts.	○	○	○	○	○
I understand the language of science.	○	○	○	○	○

Please explain your responses

APPENDIX H

INTERVIEW QUESTIONARE

5E Activity Interview

Participation in this interview is voluntary and participation or non-participation will not affect a student's grade in any way.

Unit____
Activity____
Student____
Questions:

1. What did you learn from today's activity?
2. What Science and Engineering Practice did we focus on in today's lesson?
3. How did the activity improve your skill in this practice?
4. How well did this activity help you learn the material?
5. How well did this activity help you learn the Science and Engineering Practice(s)?
6. What do you find to be the biggest benefits of doing labs, if any?
7. How do you learn best? (example: hands-on activities, visual representations, by taking notes)
8. Why is it important to learn science practices?
9. Is there anything else you would like me to know?