

A STUDY ON THE EFFECTS OF A PHENOMENON ON ACHIEVEMENT AND
STUDENT SCIENCE ATTITUDES

by

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ABSTRACT

There has been a large push in science education to incorporate the use of scientific phenomena into the unit and lesson plans. How the use of these phenomena impact student learning and science attitudes has not been studied as closely. This study measured how using a phenomenon while teaching science impacted student learning. In addition, how students' attitudes about science changed. This study also measured the impact on minority students was also measured both compared to the nontreatment group and compared to the treatment group as a whole. Students were alternated between phenomenon-based instruction and traditional instruction. This study used 3 Dimensional Assessments including claim evidence and reasonings and open-ended questions to measure student learning. Science attitudes were studied using Barry Fisher's Test of Science Related Attitudes and student interviews. The results showed a small increase in student achievement for all students during the treatment phase with a more pronounced increase for minority students. Science attitudes regarding interest and enjoyment of science and leisure and career interest in science saw increasing among the treatment group.

INTRODUCTION AND BACKGROUND

Cedar Rapids Community School District is located in Linn County, Iowa in the Eastern part of the state. It is the second largest school district in the state of Iowa, covering 133 square miles and enrolling 16,294 students (Cedar Rapids Community Schools). The district has 21 elementary schools, 6 middle schools, and 4 high schools, one being an alternative high school. Cedar Rapids is an industrial town that is home to several major manufacturers including Quaker and Cargill. They are also the headquarters of Collins Aerospace which produces engineering aviation technology. Open enrollment is of increasing concern to the district as parents elect to send their children to schools they perceive to be more suburban and affluent (Degner, M., & Kortemeyer, 2017).

I work at Wilson Middle School as a seventh-grade science teacher. Wilson has an enrollment this year of 378 students, 65% of whom are white, 18% are black, 7% Hispanic, and 8% multiracial (Iowa School Report Card). Iowa schools are ranked by the state each year using multiple measures including Iowa Assessment, attendance rates, and staff retention. Wilson has been ranked as “Priority” which is the lowest ranking possible. Only 8% of all schools receive this ranking only 54% of our students are proficient at math and 60% at reading as scored on Statewide Assessments. Wilson has 73% of students qualifying for free and reduced lunch, we started a program this year to provide all students with breakfast and lunch free of charge (Iowa Department of Education, 2017). A full-time teacher will teach 6 classes and homeroom, and our average class size is 26.7 students (Cedar Rapids Community Schools, 2018).

Our professional development this year at Wilson focused on ways to address improving student proficiencies through engagement, and how to better provide a classroom that is sensitive to students dealing with trauma. This engagement work resonated with me as I work every day trying to make science as exciting and hands-on as possible. However, I know our curriculum needs improvements as we move away from being activitymania to a practice focused on the Next Generation Science Standards and higher order thinking skills. As we work to address our gap in achievement, I have begun to think about different ways to approach teaching science that will engage as many different skill sets and learning styles as possible.

Our curriculum is currently very activity oriented but needs improvement in the teaching of science skills such as graphing, making predictions, and arguing from evidence. As part of our engagement work, I administered a survey to my students asking for feedback on both my teaching and the curriculum. The results showed that many of my students feel science labs are often predictable and leave them feeling bored, or only cover the scientific concepts superficially. They also struggled to see how different concepts or units fit together over the course of the year. This matches my feelings about the curriculum as well. Students who have little interest in science as a career, or at all, struggle to see the larger picture of why we should learn certain material, I find this to be one of the most challenging parts of my job.

I wondered how I could add more depth and rigor to my science classes while supporting the students who need additional help. One of the concerns I have been trying to address is how I could help minority students and students from low socioeconomic background be more successful in science class. As I learned about the Next Generation

Science Standards, I was drawn to the idea of the disciplinary core idea, science, and engineering standard and cross-cutting concepts for each standard working together to create a strong rope of knowledge that leads students from one concept to the next. I thought about how, by incorporating phenomena, you can lead students to deeper learning and more meaningful experiences in the classroom. While I found many resources to explain how to make a good phenomenon and 3D assessment, I found little information about how using these methods improved engagement and ultimately student learning outcomes. My experience in the classroom led me to the creation of my focus statement: What are the effects of using a phenomenon on student achievement on three-dimensional assessments? Besides my main focus question, two sub-questions were created:

1. What are the effects on achievement for minority students?
2. What are the effects on student attitudes about science?

CONCEPTUAL FRAMEWORK

As American education makes the shift to using the Next Generation Science Standards (NGSS), it stands at an important crossroads in science education (NGSS Lead States, 2013). The committee that wrote the standards had two goals: “educating all students in science, and engineering and providing the foundational knowledge for those who will become the scientists, engineers, technologists, and technicians of the future” (National Resource Council, 2012, p. 10). The standards are meant to be a holistic look at science with the idea of “all Standards, all Students” (Kahn et al., 2014 p. 38).

This work of the NGSS Standards is to address the fact that some groups have been left out of science opportunities and are underrepresented in science and engineering

programs at the post-secondary level (Rodriguez, 2015). Modern teachers need to have the cultural competence and skills to address a wide range of science skills and subjects for students from diverse backgrounds (Asowayan et al., 2017). The National Research Council worked to give teachers a tool to address this steep task by writing standards to rectify some of these inequalities by linking science to a wider lens of experiences and interests. Instruction needs to guide students through learning which is compelling and coherent learning across units and grades (National Research Council, 2014).

The framework for NGSS was built by looking at the development of the Common Core in correlation with *Race to the Top* in 2009 and using the previous science education framework *National Science Education Standards* from 1996. The standards were written with the goal of rethinking the role of assessment in the science classroom by using assessment as a measure not only of content but also of practices and crosscutting concepts (National Research Council, 2014). The NGSS is “based on the premise that authentic science approaches are critical to learning objectives” (Asowayan et al., 2017). In order to do this, we need to change the focus of our units from the acquisition of content and facts to ensuring a sense of natural phenomena.

Phenomena are used to engage students and help them process complicated concepts. A phenomenon is any observable event, natural or constructed, a teacher can use to explain a scientific concept or process (Bobrowsky, 2018). They are the anchor of learning that helps connect and clarify the concepts of the units. “Scientific phenomena can facilitate the testing of their current conceptual models, a process that can ultimately lead to students reining or discarding their current thinking” (German, 2016, p. 50). Phenomena are used to drive the instruction of a unit, moving the classroom from content

driven to process driven. The type of phenomenon used by a classroom teacher can vary from a picture or video showing a discrepant event to a question posed about a shared experience. The most important factor, however, is that they create an authentic experience for students. Students should be asking their own questions, creating their own hypotheses, and constructing conclusions based on evidence they collected while arguing what their findings mean in the larger context of scientific knowledge (Scogin & Stuessy, 2015).

For example, an earth and space unit could be centered around a simulated planned trip to Mars, allowing students to develop questions along multiple lines of investigation. They could focus on the mechanics of the trip itself, allowing for an investigation into forces and motion, or perhaps the challenges of life on another planet—creating an opportunity to explore life science topics (The CRCSD Way: Science, 2018). Throughout the project, they have the opportunity to grow in all three dimensions of the NGSS.

The NGSS are made up of the three components; the disciplinary core ideas, crosscutting concepts, and science and engineering practices. Each of these components or strands work together to create a classroom environment that mirrors the environment of an actual scientist. The Disciplinary Core Ideas (DCIs) come from four major disciplines of science: physical, life, Earth and space, and engineering. In order to be a DCI, a concept must first meet four major criteria. It must be a key organizing principle within and across disciplines. The concept should help students understand and explain many phenomena and topics in its discipline. The idea needs to have depth, so students are able to learn more extensively and experience a deeper understanding of the science

as it spirals through the K-12 curriculum. Finally, the DCI should be relevant and useful to modern students (Golan Duncan & Cavera, 2015).

The Crosscutting Concepts (CC) are common themes that can be found across all disciplines of science and give students the tools they need to draw connections between them (Krajcik, et al., 2014). They also help students look at a phenomenon from different perspectives. When students use CCs, they are able to view phenomena through a different lens. Whereas looking at information in terms of structure or function might be the traditional way if you consider what patterns might emerge from the data you might discover a completely new piece of information (Duncan & Cavera, 2015). “Without a doubt, academic success depends on a student’s ability to establish cross-subject links” (Asowayan et al., 2017, p. 69).

The science and engineering practices (SEP) help students view science as an active endeavor that is performed every day. They are the intellectual tools that scientists use to perform science in the community. Oftentimes students think science is simply a game to be solved with a correct answer, or a winner and loser but that is not what true science is like. “The SEPs described in the Framework and NGSS are an attempt to capture the essence of how the scientific community works to generate knowledge” (Golan Duncan & Cavera, 2015, p. 19). This demonstrates the SEPs are really about a set of skills that students should use to engage in science.

Together these three fundamental components of science, the content, the practice, and the lens, come together to create a science curriculum that places the emphasis on deep meaningful learning experiences and not activitymania or content that is a mile wide and an inch deep. For many years, science curriculum placed its focus on

the acquisition of content. However, the National Research Council in *Taking Science to School* has clearly shown that learning cannot be separated from the doing of science. If we want students to learn content and apply their knowledge, they must use the SEPs and CCs with the DCIs together (2007). The NGSS fundamentally shifts the focus and moves to place the emphasis on students learning to figure out phenomena and design solutions to problems (Krajcik, 2015).

To this end, teachers must work to create curriculum and assessments that support students as they strive to achieve these new and difficult standards. A teacher's "main task is to find the proper ways of teaching science and engineering in compliance with those values" (Asowayan et al., 2017, p. 65). One thing teachers can do to support and encourage students, especially minority and at-risk students, is to create phenomena to tie units and ideas together. According to Scogin and Stuessy, the best way to create an environment where students are successful in achieving the goals of NGSS is using a "computer-mediated collaborative learning environment intertwining scientific inquiry, classroom instruction, and online mentoring" (2015, p. 312). Educators are preparing students for jobs that do not yet exist, but the skills they develop from each strand of an NGSS curriculum will give them the skills they need to be successful.

Phenomena need to be connected to the performance expectations that educators create for a unit. "Well-planned and effective assessment methods are critical to theme-based lessons" (Melear & Lunsford, 2007, p. 52). The performance expectations are not standards like those that have been written in the past with the main focus being *Students will know* or *Students will understand* because measuring what students know or understand can be a nebulous task. Instead, the NGSS has created performance

expectations that clearly state how students should demonstrate their knowledge of each of the three parts of the standard (Krajcik et al, 2014). Phenomena give a unit the framework in which to do this task. Students can show their learning while improving their ability to explain the world around them and create solutions for real-life problems our society is currently facing.

Another important component of writing phenomena for three-dimensional assessments are the evidence statements provided by the standards. “Evidence statements explain how to assess the disciplinary core idea, science, and engineering practice, and crosscutting concept as integrated strands, whereas performance expectations explain each dimension separately” (German, 2017, p. 29). When working backward, as the teacher creates an assessment before beginning a unit, it is important to use evidence statements to integrate all three strands of the PE into a phenomenon. It is also important to listen to the questions that students generate on their own and use those to guide instruction. The strands of the standard and their evidence statements should not be reduced to a checklist, but instead used as a guide for instruction to help the teacher understand what skills a student should be practicing and grow in (German, 2017).

Three-dimensional formative assessment should allow the instructor to create a sense of wonder in his or her classroom. Science phenomena can spark a student’s curiosity, and the strands give teachers the power to create a classroom where student questions drive instruction rather than mindless memorization of facts. Together they can create a curriculum that truly helps students to reach their highest potential.

METHODOLOGY

This project followed six sections of seventh grade integrated science with four classes being assigned to the treatment group ($N=53$) and two classes assigned to the nontreatment group ($N=45$). The treatment group consisted of 26 females and 27 males while the nontreatment group consisted of 23 females and 22 males. The treatment group contained a class supported by a paraprofessional. This paraprofessional helps six students with moderate intellectual disabilities integrate into my classroom. She provides a supported least restrictive environment for all students to learn. The treatment and nontreatment group were flipped for the second unit and returned to the original organization for the third unit.

This capstone project followed the use of phenomena in teaching throughout the instruction of two NGSS Standards: “Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history” and “Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system” (NGSS Lead States, 2013). The research methodology for this project received an exemption by the Montana State University Review Board and compliance for working with human subjects was maintained (Appendix A). The focus of the project was to measure if using phenomenon during the teaching of a standard impacted student achievement as demonstrated on various three-dimensional (3D) assessments.

Additionally, the project hoped to measure the different impact of the phenomenon on students from various underrepresented backgrounds. Finally, the project measured student engagement when employing a phenomenon while teaching. These

three questions were investigated using pre and post-tests, surveys, observations, treatment/non-treatment assessment comparisons, and interviews. The data was analyzed by category comparing treatment and nontreatment and comparing minority data. Minority status was established using parent supplied demographic data found in our learning management system, PowerSchool.

Treatment Description

During this study, six seventh grade integrated science classes were divided into three treatment classes and three nontreatment groups. Each group consisted of approximately 40 students with mixed ability levels. The study covered two standards each lasting approximately five weeks in duration, and focused instruction around a natural phenomenon. The phenomenon was for students to use as a reference. It allowed them to explore and visualize their learning, and understand how science is connected to the everyday world around them.

In the first unit, students constructed a scientific explanation-based on evidence from rock-strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history (NGSS Standard MS-ESS 1-4). The anchor phenomenon was the creation of the Grand Canyon. The second unit focused around potential and kinetic energy (Standard MS-PS 3-2). The standard called for the evaluation of potential energy, but after consulting with the district science curriculum committee the decision was made to include kinetic energy. The phenomenon used was the construction of rollercoasters. Students in the treatment group had the phenomenon incorporated into their science class almost every day and were routinely asked to make connections back to the phenomena. Students in the nontreatment group completed the same or similar activities each day as

the treatment group and were given all the same assessments but did not have their learning connected to any phenomenon. The data was analyzed using t-tests, normalized gains, trends, and averages.

Instrument Description

Prior to the start of the project, both groups of students took the Test of Science Related Attitudes by Barry Fraser (Appendix B). The survey was administered again after the project to compare growth both within and between treatment and nontreatment groups. The Test of Science Related Attitudes is a widely used survey used to better understand the broad spectrum of student science-related attitudes. The test was developed by Barry Fraser in 1981 and tested with 1,337 students to establish the validity and reliability of the test. The survey consists of 70 items sorted into 7 different scales: Social Implications of Science (S), Normality of Scientists (N), Attitude to Scientific Inquiry (I), Adoption of Scientific Attitudes (A), Enjoyment of Science Lessons (E), Leisure Interest in Science (L), and Career Interest in Science (C). Students respond to each item with one of five responses based on a Likert scale: Strongly Agree, Agree, Uncertain, Disagree, and Strongly Disagree.

Thirty-five questions reflected positive attitudes towards science and 35 questions point towards negative attitudes. For questions about a positive attitude, the score Strongly Agree was the highest score possible of five and went down to one for Strongly Disagree. For questions that assessed a negative science attitude, the reverse was true with Strongly Disagree scoring five going down to one for Strongly Agree. The points for each of the seven scales and the entire survey were averaged to describe the students' science attitudes. Positive attitudes were correlated with higher scores and negative

attitudes were correlated with lower scores. The student surveys were analyzed for trends and patterns with a T-Test looking for significant differences between groups and means and trends within the data.

At the beginning of instruction for each standard, a pretest was administered. The Grand Canyon Earth Science assessment was the first instrument administered. The assessment addressed standard MS-ESS 1-4 and consisted of five multiple choice questions and three short answer responses (Appendix C). The questions were taken from the Stemscores curriculum and have been edited to be three-dimensional questions. Each of the multiple-choice questions requires the interpretation of a diagram showing various depictions of stratigraphic columns. The short answer response questions build on each other for information with the final question requiring students to interpret a diagram. The Grand Canyon Earth Science Assessment was analyzed after the completion of the standard using the normalized gain test. The author broke the data into three levels of gain groups with low gains considered to be gains below .3, medium gains ranging from .3 to .7 and high gains greater than .7 (Hake, 1998). For this project, a normalized g of .3 or higher was considered the threshold for indicating significant student learning.

The second assessment was the Potential and Kinetic Rollercoaster Physical Science Assessment (Appendix D). For the multiple-choice portion, three questions ask students to interpret diagrams showing various moving and stationary objects, requiring students to interpret their respective potential and kinetic energy. There was one question with a data table asking students about the relationship between mass and kinetic energy, and a final multiple-choice question asking students to determine the research question for an experiment on potential and kinetic energy. The open-ended questions asked the

student to consider the energy of a rollercoaster at different points on the track. These questions were followed by two questions about the placement of a truck and soccer balls, requiring students to interpret the potential and kinetic energy. This assessment was analyzed using a normalized gain test.

During the study, both treatment and nontreatment groups took the Washburn Phenomenon Survey (Appendix E). The Washburn Survey consisted of 11 questions which asked students about how well they understood how their science class experiences and assessment. These questions asked how classes related to each other and the greater outside world, as well as how confident they feel about their work in science class. Ten of the questions were Likert type questions consisting of four ranked responses from strongly agree to strongly disagree with no neutral option. The 11th question was a short answer question asking if the student had any further questions or observations to share. The survey was given three times during the study, once within each mini-unit. Responses were analyzed for trends and patterns both between and within groups.

A small group of students completed the Washburn Engagement Interview (Appendix F). The goal of these interviews was to gain a deeper insight into what students were thinking and feeling in both the treatment and nontreatment group. The interviews were conducted midway through the project as nontreatment and treatment groups switched and at the end of the project. The data was analyzed for trends and important insights into student learning and science attitudes.

Each unit also had a culminating project that was tied to the phenomenon for the treatment group, but not part of the overarching narrative for the non-treatment group. The Earth science unit asked students to create a timeline of time periods throughout

history. Additionally, the treatment group needed to add the rock layers of the Grand Canyon. For the potential and kinetic energy unit, the treatment group created marble and insulation foam tube rollercoasters and the non-treatment group created rubber band race cars.

These projects were then used as a base for a three-dimensional assessment in the form of a Claim Evidence Reasoning writing (CER). The Grand Canyon Earth Science unit contained a CER asking the student to write a scientific explanation that describes how the strata of the Grand Canyon tells us about the past. Students were asked to write at least one sentence for their claim, three sentences for their evidence and three sentences for their reasoning (Appendix G). For the potential and kinetic energy unit, the CER asked students to explain where, in a pictured rollercoaster, where potential and kinetic energy was the greatest (Appendix H). Student expectations were similar in both units. All CERs were evaluated with a rubric created for the curriculum from Stemsscopes (Appendix I) with the exclusion of the student rebuttal section. This section was given a standards-based grade developed by Cedar Rapids Community School District of Exceeding, Proficient, Developing, or Insufficient for their writing. These scores were then turned into a numeric score ranging from 5 to 1, high to low. In unit claim evidence reasonings and classroom assessment tasks were analyzed for mean, trends and patterns.

The Data Triangulation Matrix (Table 1) identifies the methodology used to investigate each focus question of this capstone project.

Table 1
Data Triangulation Matrix

Focus Questions	Data Source 1	Data Source 2	Data Source 3
<i>Primary Question:</i> 1. How does using a phenomenon impact student achievement on 3D assessments?	Compare scores on earth history unit between treatment and non-treatment groups	Compare scores on potential and kinetic energy unit between treatment and non-treatment groups	Compare score on claim evidence reasonings between treatment and nontreatment groups
<i>Sub-Questions:</i> 2. How does using a phenomenon impact students beliefs about science?	Pre- Mid- and Post-Treatment Surveys	Pre- Mid- and Post-Treatment Interviews	TOSRA Data
3. How does using a phenomenon impact minority and students with additional barriers to education?	Compare scores for subgroups on between treatment and non-treatment groups	TOSRA Data for Subgroups	Pre- Mid- and Post-Treatment Surveys for subgroups

DATA ANALYSIS

Normalized Gain

The normalized gain for Earth History from the pre and posttest of 47 students in the treatment group showed a mean gain of .35 (Figure 1). The results showed an average posttest score of 3.5 out of 8 compared to the pretest score of 1.5. Only 6% of students had a negative normalized gain. Twenty-five students or 55.5% had normalized gains greater than .3, which Hake indicated as his threshold between low and medium gains (1998). One student shared their opinion about how these science classes are structured around a phenomenon saying, “I feel like we prepare for the test as we learn

about science. I feel very prepared for the test because it is using ideas that we have already learned about and used in science class every day.”

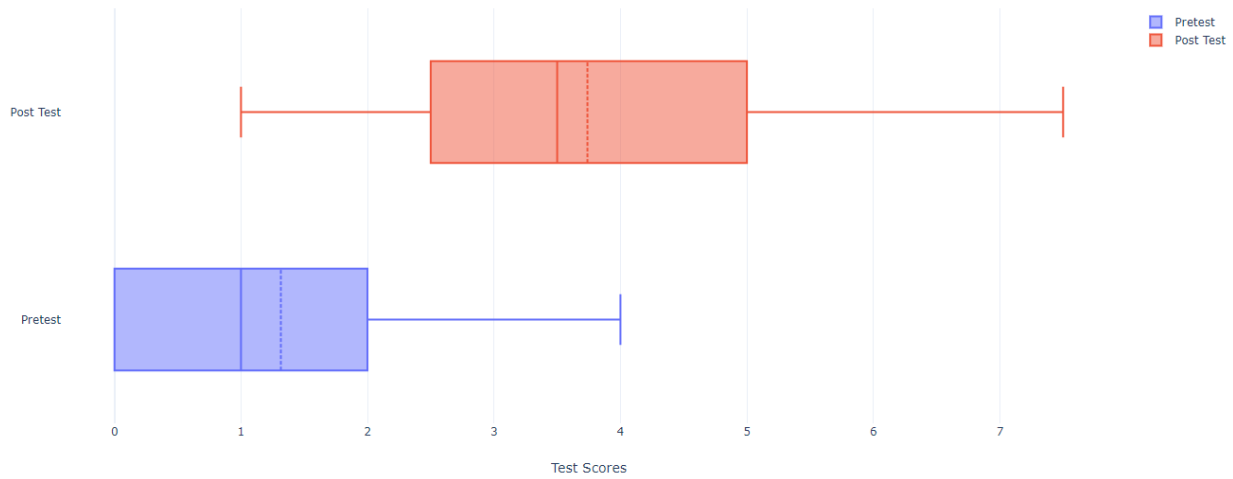


Figure 1. Earth science treatment group pre and post-test box-whisker plot, (N=47).

The normalized gain for the Earth Science nontreatment group of 35 students was .34 (Figure 2). Students raised their scores from 1.9 to 4.1 out of 8 possible. Sixty percent of students had a normalized score above .3 making it a medium gain, while 14% of students had a negative normalized gain.

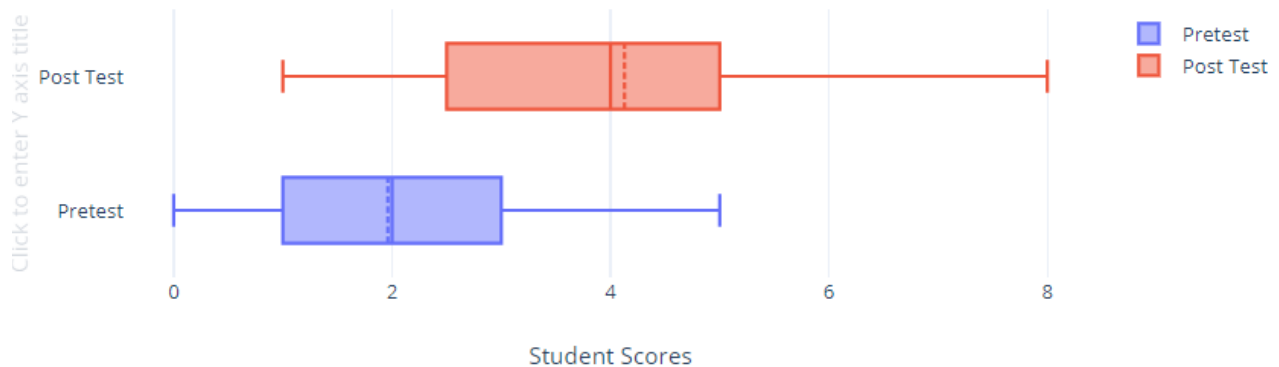


Figure 2. Earth science nontreatment pre and post-test box-whisker plot, (N=35).

Looking at the data broken apart to understand how minority students fared show the treatment group with a normalized gain of .34 (Figure 3). The average mean score increased from 1.18 to 3.5 out of eight. The nontreatment group saw a normalized gain of

.3. The average mean increase was from 1.25 to 3.45. There were no students with negative normalized gains among minority students in the treatment group and 10% of students in the nontreatment group had a negative normalized gain. The normalized gain for students who identified as Caucasian was .37 for the treatment group and .36 for the nontreatment group.

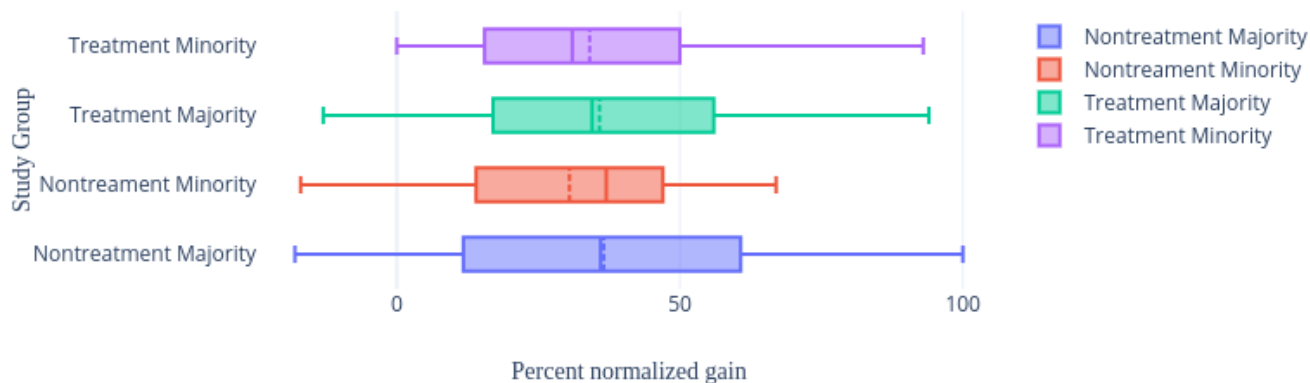


Figure 3. Normalized gain percentages for earth science pre post-test, ($N=82$).

The second unit was Potential and Kinetic Energy. The results showed the normalized gain of the treatment group was .54 ($N=45$). Hake would classify this as a medium-gain (1998). Eleven students, or 24%, showed a high-gain greater than .7, while two students showed a negative normalized gain. The treatment group saw student's scores grow from 2.9 to 5.75. Looking only at minority data, students had a mean average gain of .54 consistent with the whole group data. No students had a negative normalized gain score ($N=14$).

The nontreatment group results showed a normalized gain of .28. This is below Hake's cutoff of .3 for a medium-gain normalized score ($N=22$). Four students had negative growth, and two students had above a .7 for a high-gain normalized score. Minority students saw a normalized gain of -.033 ($N=14$). Only two students showed a medium-gain and no students could be classified as a high-gain. There were three outlier values for the potential and kinetic energy treatment group; all low scores and one additional low outlier score in the minority treatment group.

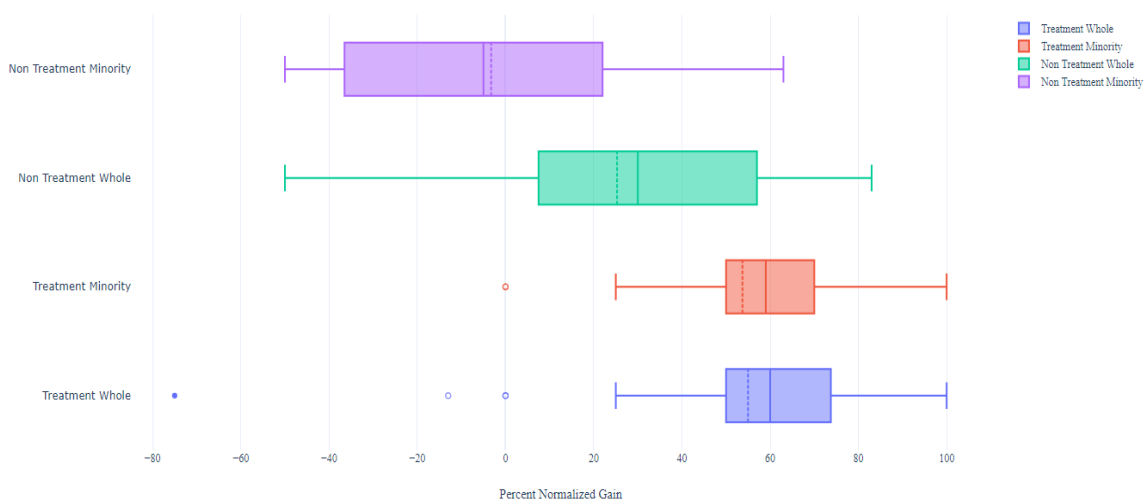


Figure 4. Potential and kinetic energy test normalized gain percentages, ($N=67$).

The Claim Evidence Reasonings written by the students showed that students involved in the treatment group had a mean score of 2.16 (Figure 5). This is compared to the nontreatment groups mean score of 1.94 ($N=82$). The nontreatment group contained one student who's writing analysis scored as exemplary. Within minority student groups the treatment group had a mean score of 1.92 while the nontreatment group earned a mean score of 1.67.

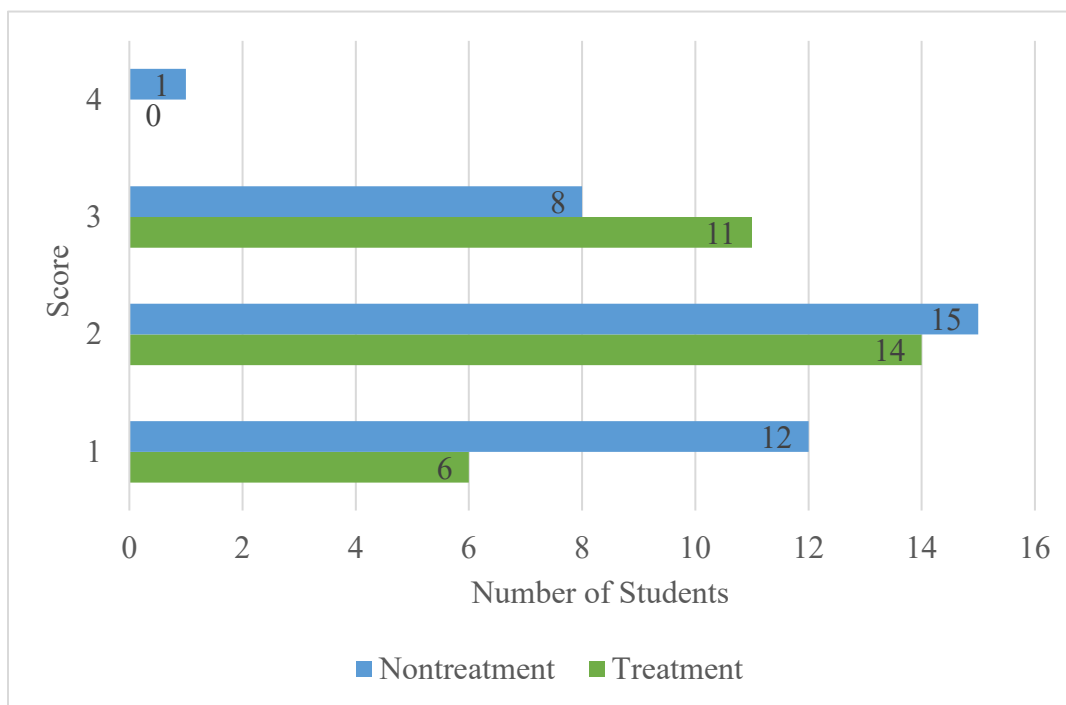


Figure 5. Nontreatment and treatment earth science claim evidence reasoning student scores, ($N=82$).

The results from the Potential and Kinetic Energy CER show the treatment group had a mean score of 2.36 (Figure 6). The nontreatment group had a mean score of 1.92 ($N= 82$). The treatment group was also the only group to have any students earn an exemplary score on their Claim Evidence Reasoning showing above grade level thinking and reasoning. For minority populations within the treatment group, there was a mean score of 2.26 which is higher than the whole group nontreatment group. The minority cut of the nontreatment group had a mean of 1.62 which is comparable to the mean scored on the first assessment.

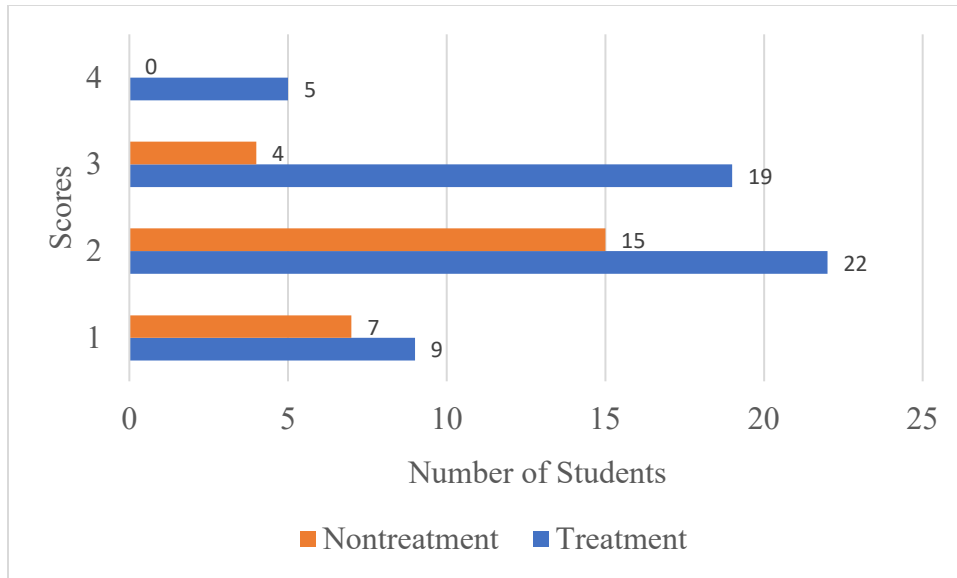


Figure 6. Treatment and nontreatment potential and kinetic energy claim evidence reasoning scores, ($N=82$).

Science Attitudes

The results of the Test of Science Related Attitudes (TOSRA) showed an increase in mean score from 31.84 to 35.12 with a p-value of .0390 for the treatment group after one round of data collection. The nontreatment group showed an increase in mean score from 31.84 to 32.89, which with a p-value of -.59, is not a significant change. Within the categories of the survey, there were many interesting findings. Each category had a maximum score of 50. This score is related to the student selected response between 1 and 5. There was only a small difference between the pretest and posttest for societal implications of science (S), with the pretest having a mean gain of .2 rising from 3.22 to 3.492 ($p=.153$) which is not a significant increase in students' beliefs in favorable attitudes toward science and scientists (Figure 7).

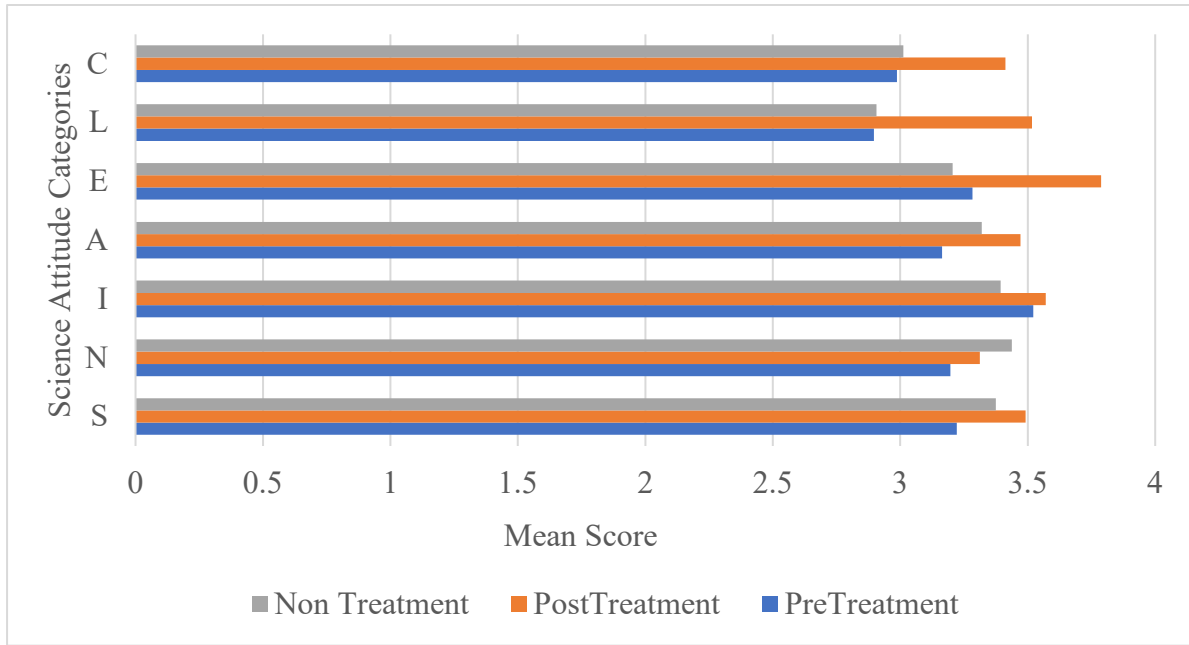


Figure 7. Pre, post, and non-treatment groups mean group scores for seven categories of tostra survey, ($n=32$). Key: s- societal implications of science, a-adoption of science attitudes, n-normality of science, e-enjoyment of science lessons, i-attitude towards science inquiry, l-leisure interest in science, c-career interest in science

The largest increase was for category Leisure Interest in Science (L) which saw a mean increase of .610 from 2.897 to 3.517. The nontreatment group stayed almost the same with a mean of 2.906. Another category that saw a large increase was Enjoyment of Science Lessons (E), which showed a mean gain of .505 from 3.283 to 3.788 ($p=.016$) while the nontreatment group saw a decrease to 3.206 ($p=.958$). The final category with a large increase was career interest in science (C), which saw a mean gain of .4255 ($p=.0279$) from 2.98 to 3.41. Once again in this category, the nontreatment showed virtually no gain with an ending mean of 3.01. One student, commenting on the use of phenomenon said, “I feel like we do more this year in science class [with a phenomenon] than last year, and I definitely feel like I am learning more.”

In category normality of scientists (N), the nontreatment group showed a higher mean gain than the treatment group. The nontreatment group gained .242 mean points

compared to the treatment groups gain of .117 points. Although with p values of .103 for the nontreatment group and .386 for the nontreatment group, neither indicates a significant difference from the pretreatment survey.

One should also look at the difference in survey results for minority and underrepresented populations. The mean gain for minority populations before administering the treatment was 3.01 compared to the overall pretreatment mean of 3.19. Minority populations showed a mean gain of .44 rising to 3.45 ($p=.403$). The growth of overall science attitudes in nontreatment populations was not significant based on the T-Test.

The difference between treatment and nontreatment total group means was not significant, but three categories within the survey did show significant difference between treatment and nontreatment groups. Every category showed a mean growth for minority students in the treatment group except for the normality of scientists (Figure 8). The category that showed the most gain for minority students was Leisure Interest in Science (L). This category showed a gain of .673 to end with a mean score of 3.518. It was the largest gain shown by any group for any category. One boy spoke of his increased interest in science after two units using a phenomenon saying, “The thing I like best about science is how you teach it and how much you seem to enjoy science yourself and enjoy teaching us about it [science].”

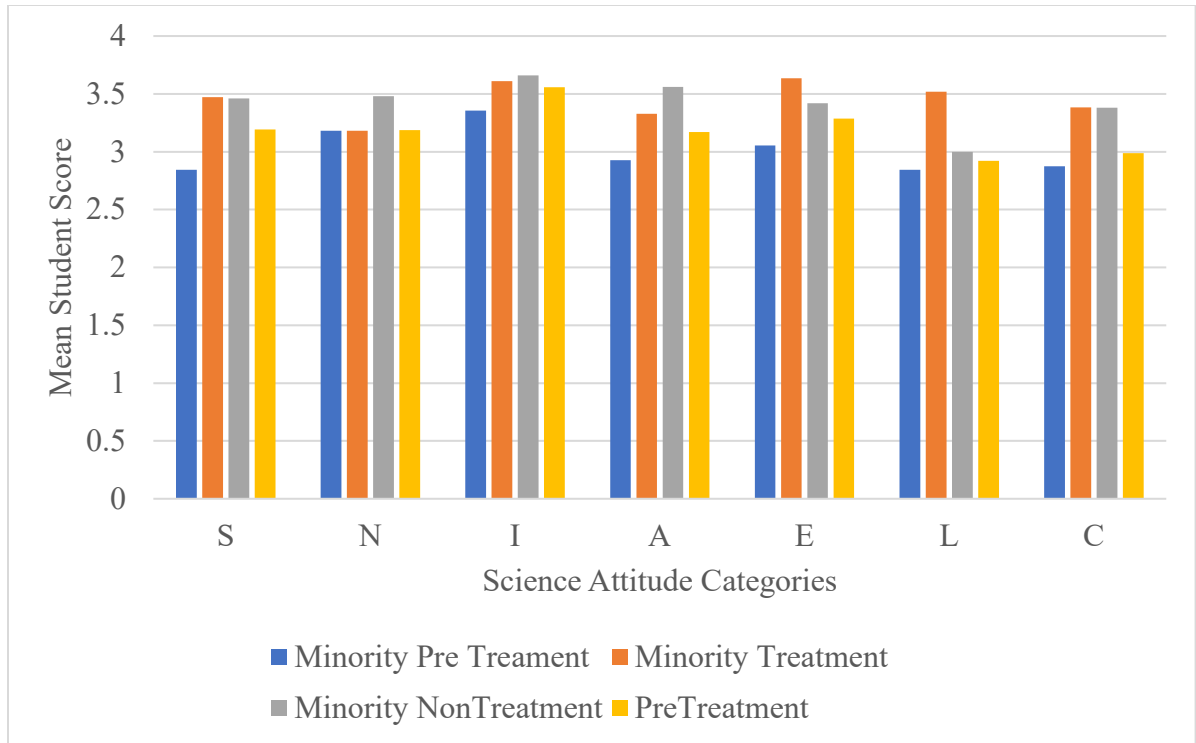


Figure 8. Pre, post, and non-treatment tosra scores for minority groups with whole group pretreatment scores, ($n=20$). Key: s- societal implications of science, a-adoption of science attitudes, n-normality of science, e-enjoyment of science lessons, i-attitude towards science inquiry, l-leisure interest in science, c-career interest in science

Both category social implications of science (S), and career interest in science (C) showed no difference between the treatment and nontreatment group even though category C showed a significant difference when looking at the whole group data ($p=.0279$). The results of science attitudes measured with the TOSRA test were lower in every category for minority groups except for category normality of scientists (N), which was the same for both minority and whole group pretest scores.

The nontreatment group showed greater growth than the treatment group for category adoption of scientific attitudes (A) and normality of scientists (N). The mean average for category A grew from 2.927 to 3.56 ($p=.201$) for the nontreatment group, a gain of .633 while the treatment group saw a gain of only .4 to 3.327 ($p=.310$). Neither of

these gains in mean was significant. The nontreatment group of category N showed a mean growth of .298 from a 3.182 to 3.48 ($p=.560$). A small sample size of minority students in the nontreatment group completing the survey may have influenced the significance of the results even though the overall numbers show growth.

Engagement

According to the Washburn Phenomenon Survey, 71% of students preferred the inclusion of a phenomenon within their Earth science unit ($N=38$). During the Potential and Kinetic Energy Unit, 84.4% of student reported liking a phenomenon ($N=45$). A student reflecting on her experiences using a phenomenon in science class saying, “This class is loud, but we DO things, we don’t just watch videos and fill out worksheets.” Another student said, “Last year it was like the teacher taught us something then we took the test, but this year it's like we have a theme and we study it and do something with it and then take a test over what we learned.” Additionally, 75.6% of students could see the connection between the phenomenon and the questions on the assessment. One student said, “I like to have a phenomenon because it helps me remember from one day to the next.” Although one student did report that “the classroom is kind of chaotic.”

The Washburn Phenomenon Survey showed that 86.9% of students could make a connection between their science lessons and the unit assessment for the Earth science unit ($N=38$). One student liked that she had something to talk about to with her mom regarding what she learned during school that day. She could understand and explain why she learned it. The nontreatment group showed that 65.7 % of students could make a connection between the day’s lesson and the final assessment for the Earth science unit ($N=32$). For the Potential and Kinetic Energy Unit, 82.5 % of students reported being

able to make connections from the daily lessons to the unit assessment ($N=45$). The nontreatment group reported making connections to the assessment 88.9% of the time ($N=20$).

For students who were in the treatment group during both units, they reported they could connect their lessons to the assessment 94.4% of the time ($N=18$). One student stated, “I can definitely see a connection between our learning and the test. I like that things are connected to a larger theme. It helps me learn.” Another student, who was not in the treatment group for the Earth Science unit, when asked how learning about Earth Science connected to her daily life responded, “It doesn’t really, does it? It is just for scientists to see how old the Earth is.”

Students that were part of the treatment group for the Earth science unit reported feeling confident about the content of the assessment and the questions on the test 76.3% of the time compared to 56.3% for the nontreatment group. The treatment group for the second unit felt they understood what the questions were asking them to do on the assessment 66.7% of the time ($N=45$). “I like that we start out with a simple idea and simple questions and slowly get harder and more complex. It makes the test seem easier,” one student reported.

After the first unit in the treatment group, 71.1% of students reported feeling like they were strong science students compared to 56% of students in the nontreatment group. Looking at minority students involved with the first treatment group, 84% felt like stronger science students ($N=19$). This was higher than the whole group in the nontreatment group only 40% of students reported feeling like strong science students ($N=10$). During an interview when asked about how he felt using a phenomenon and

science in general, a student said, “The fact that having everything related helps me because it is not all over the place. Every day I know it is going to be related and it just makes me feel a little bit better.”

INTERPRETATIONS AND CONCLUSIONS

The goal of this study was to determine what sort of impact using phenomenon have on how students learn science and how they feel about science. This study, across two units, has led to several possible conclusions about how using a phenomenon can impact students in the middle school science classroom. First, the achievement data for students does not look very remarkable when taken as a whole. However, when the data is looked at in pieces, it shows how using a phenomenon helps aid students who have additional barriers to learning and encourage others to engage more and have a greater interest in science. This does have a positive impact on student achievement.

Student growth was especially pronounced in the second unit, during which we experienced a record number of snow days. The normalized gain of the treatment group was a medium-gain slightly higher than the first unit’s growth. Minority students within the treatment group had the same mean gain as the whole group, .34. While the nontreatment group showed some growth, it did not meet Fraser’s .3 threshold of growth with a normalized gain of .24. Importantly though the minority students within that group lost learning over the course of the unit with a normalized gain of -.033.

One could conclude that the added disruption of the snow days was especially negative for students who already struggle with school. By using the phenomenon as a reference, the treatment group was able to build a mental model with continuity which helps offset the disruptions. In perfect conditions, student learning may not show a large

benefit from using a phenomenon. However, when learning is not a smooth continuous event, a phenomenon can help students build a framework to put the pieces of a unit together in order to better understand the overall concept.

Student attitudes about science became more positive when I used a phenomenon that had them think about using science in their leisure time or everyday life, as well as consider science as a career. They also reported enjoying their science lessons much more. They felt like they understood the big picture of how what they were learning when one day connected seamlessly to the next. It did not have an impact on how student viewed scientists as normal people or how they felt society viewed scientists. This does not surprise me, as several of them express feelings that science class cannot be compared to actual science and scientists.

Some uncontrollable circumstances took place when executing this study. This project was originally meant to look at three units but lack of time due to inclement weather closings only allowed for two units. Also, our school has such a high population of students who qualify for free and reduced lunch provides free breakfast and lunch to all students. Due to this availability, participation data is not collected. Therefore, I could not compare data across socioeconomic status. The data which was available showed two or three students per class who would qualify as a middle-class student making any inferences difficult invalid.

VALUE

I would be lying if I said that the first time I heard about using a phenomenon to teach science I did not think it was a hook dressed up fancy. Once I better-understood phenomena and their intended use, to weave through a unit and provide a mental anchor

for students to wrap their new understandings around, I came to appreciate the idea. I was still was leery about whether, and to what degree a phenomenon would impact student learning. Initially seemed like a fun idea, but probably not necessary. I theorized the impacts on students would be modest at best.

Seeing the impact of a phenomenon on the learning of students who already struggle with school really changed my perspective on how I address equity in my classroom. By providing a common event for all students to use, I am creating greater access to the content. In the Potential and Kinetic Energy Unit, I used a roller coaster as a phenomenon. Once we got started it came to my attention that over half of my students had never been on a rollercoaster. Although we watched a first-person ride on a rollercoaster, we all know that is not the same. Understanding the common experiences of your students is an important part of creating a great anchoring phenomenon.

Through this project, I learned a new way of helping my students see the world around them and look beyond Cedar Rapids, Iowa to the wider world. When learning about the Grand Canyon, we took a point of view flight through the Canyon. For several students, this was the first time they had seen or even heard of the Grand Canyon. Beyond Earth science aspect of the unit, they also had the opportunity to see and learn about one of our country's treasures. As stated before, many of my students had never been on a rollercoaster when we started the Potential and Kinetic Energy Unit. I had not considered that as I was planning the unit and I have been reminded several times throughout my project of the place of privilege I am teaching from and how important it is to remember when considering activities and phenomenon. After showing my students a video of Kingda Ka in New Jersey, they were all excited to ride a rollercoaster next

year when they go on a class trip. Many of them told me they wished to go to New Jersey someday and ride the Kingda Ka. The students in my nontreatment group did not show the level of enthusiasm for learning or interest in the greater world.

I could see firsthand and without assessments how much using a phenomenon increased students' enjoyment of science class, especially when the projects were connected to the phenomena. Students were excited to come to class each day. Many students who were previously unengaged not only showed me but even other teachers, what they were learning about. Students who never chose to participate felt like part of the classroom. During the building of the rollercoasters, I had engagement from students who I had never seen join in the classroom activities before. And on top of that most of them could describe the changes in energy over the course of the rollercoaster correctly.

This project taught me the importance of knowing what your students know and giving them the tools to create explanations in their own minds not just giving them the explanations. Learning is more meaningful when students feel they have a vested interest in the outcome, and also when they feel like they have a chance at one day applying what they know in the real world. Learning science isn't about memorizing a bunch of facts and equations, it is about creating a way of thinking, building, and refining our mental models of how the world around us works.

For further study, I would like to investigate how student learning is impacted over a greater period and also how the phenomenon can be more fully incorporated into lessons and units. I am part of the district level curriculum committee and will definitely be advocating for the use of well-integrated phenomenon into our curriculum district-wide. I would also like to get student input on what sort of phenomena they are interested

in to help drive that conversation. I would like more practice writing three-dimensional assessments. I can truly say this project has made me a better, more reflective teacher and I am excited to take the next steps of incorporating more phenomenon into my teaching, including lesson and assessment phenomena.

REFERENCES CITED

- Asowayan, A. A., Ashreef, S. Y., & Omar, S. H. (2017). A Systematic Review: The Next Generation Science Standards and Increased Cultural Diversity. *English Language Teaching*, 10(10), 63–76. Retrieved from <http://search.ebscohost.com.proxybz.lib.montana.edu/login.aspx?direct=true&db=eric&AN=EJ1153875&site=ehost-live>
- Bobrowsky, Matt & Korhonen, Mikko & Kohtamäki, Jukka. (2014). Using Physical Science Gadgets and Gizmos (Grades 6-8): Phenomenon-Based Learning.
- Cedar Rapids Community School District. (2018). The CRCSD Way: Science [Letter to Cedar Rapids Families]. Cedar Rapids, Iowa.
- Cedar Rapids Community Schools. (2018). Welcome To Cedar Rapids Community School District. Retrieved December 9, 2018, from <http://www.cr.k12.ia.us/>
- Degner, M., & Kortemeyer, A. (2017). *Enrollment, Demographics, and Class Size Report* [Pamphlet]. Iowa City, IA: Iowa City Community School District. Retrieved from [https://www.iowacityschools.org/cms/lib/IA01903939/Centricity/Domain/10/Enrollment Report 2017-18 Final.pdf](https://www.iowacityschools.org/cms/lib/IA01903939/Centricity/Domain/10/Enrollment%20Report%202017-18%20Final.pdf)
- German, S. (2017, Summer). Transitioning to three-dimensional learning with evidence statements. *Science Scope*, 40(9), 28+. Retrieved February 27, 2018, from http://link.galegroup.com.proxybz.lib.montana.edu/apps/doc/A503273245/AONE?u=mtlib_1_1123&sid=AONE&xid=e8f17c8a
- German, S. (2016). Phenomenal engagement. *Science Scope*, 40(2), 50-51. Retrieved September 25, 2018, from <https://search-proquest-com.proxybz.lib.montana.edu:3443/docview/1823824015?accountid=28148>
- German, S. (2017, September). Written assessment in three dimensions. *Science Scope*, 41(1), 28+. Retrieved March 1, 2018, from http://link.galegroup.com.proxybz.lib.montana.edu/apps/doc/A503459735/AONE?u=mtlib_1_1123&sid=AONE&xid=f90d19be
- Golan Duncan, R., & Cavera, V. (2015). *DCIs, SEPs, and CCs, Oh My! Understanding the Three Dimensions of the NGSS*. *Science Scope*, 039(02), 16-20. Retrieved March 1, 2018, from http://dx.doi.org/10.2505/4/ss15_039_02_50
- Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66(1), 64-74. doi:10.1119/1.18809
- Iowa Department of Education. (2017). Iowa School Report Card: Wilson Middle School. Retrieved April 17, 2018, from <https://reports.educateiowa.gov/schoolreportcard/home/reportcard?yr=2017&sch=10530236&type=middle>

- Kahn, S., Wild, T., Woolsey, L., & Haegele, J. A. (2014). Let's Get Physical. *Science and Children*, 51(5), 37–43. Retrieved from <http://search.ebscohost.com.proxybz.lib.montana.edu/login.aspx?direct=true&db=eric&AN=EJ1035146&site=ehost-live>
- Krajcik, J., Codere, S., Dahsah, C., Bayer, R., & Mun, K. (2014). Planning instruction to meet the intent of the Next Generation Science Standards. *Journal of Science Teacher Education*, 25(2), 157-175. Retrieved March 2, 2018, from <http://dx.doi.org.proxybz.lib.montana.edu/10.1007/s10972-014-9383-2>
- Krajcik, J. (2015). Three-Dimensional Instruction: Using a New Type of Teaching in the Science Classroom. *Science And Children*, 053(03), 6-8. Retrieved February 27, 2018, from http://dx.doi.org/10.2505/4/sc15_053_03_6
- Melear, C. T., & Lunsford, E. (2007). Worms: Cultivate Our Curriculum: A Long-Term, Theme-Based Unit. *Science Activities*, 44(2), 48–55. <https://doi-org.proxybz.lib.montana.edu/3443/10.3200/SATS.44.2.48-54>
- National Research Council. 2012. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13165>
- National Research Council. (2014). *Developing Assessments for the Next Generation Science Standards*. Washington, DC: The National Academies Press. Retrieved March 1, 2018, from <https://doi.org/10.17226/18409>.
- National Research Council. 2007. *Taking Science to School: Learning and Teaching Science in Grades K-8*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/11625>
- NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.
- Rodriguez, A. J. (2015). What about a Dimension of Engagement, Equity, and Diversity Practices? A Critique of the Next Generation Science Standards. *Journal of Research in Science Teaching*, 52(7), 1031–1051. Retrieved from <http://search.ebscohost.com.proxybz.lib.montana.edu/login.aspx?direct=true&db=eric&AN=EJ1071553&site=ehost-live>
- Scogin, S. C., & Stuessy, C. L. (2015). Encouraging Greater Student Inquiry Engagement in Science Through Motivational Support by Online Scientist-Mentors. *Science Education*, 99(2), 312–349. <https://doi-org.proxybz.lib.montana.edu/3443/10.1002/sce.21145>

APPENDICES

APPENDIX A
IRB EXEMPTION FORM



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
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Chair: Mark Quinn
 406-994-4707
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Administrator:
 Cheryl Johnson
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MEMORANDUM

TO: Megan Washburn and John Graves
FROM: Mark Quinn, Chair *Mark Quinn CQ*
DATE: November 26, 2018
RE: "Effect of Using a Phenomena on Student Achievement and Engagement with 3-Dimensional Assessment in Next Generation Science Standards (NGSS)" [MW112518-EX]

The above research, described in your submission of November 20, 2018, 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

TEST OF SCIENCE RELATED ATTITUDES

TOSRA²⁸

TEST OF SCIENCE-RELATED ATTITUDES

Barry J. Fraser

DIRECTIONS

- 1 This test contains a number of statements about science. You will be asked what you yourself think about these statements. There are no 'right' or 'wrong' answers. Your opinion is what is wanted.
- 2 All answers should be given on the separate Answer Sheet. Please do not write on this booklet.
- 3 For each statement, draw a circle around
 - SA if you **STRONGLY AGREE** with the statement;
 - A if you **AGREE** with the statement;
 - N if you are **NOT SURE**;
 - D if you **DISAGREE** with the statement;
 - SD if you **STRONGLY DISAGREE** with the statement.

Practice Item

- 0 It would be interesting to learn about boats.

Suppose that you **AGREE** with this statement, then you would circle A on your Answer Sheet, like this:

- 0 SA (A) N D SD

- 4 If you change your mind about an answer, cross it out and circle another one.

- 5 Although some statements in this test are fairly similar to other statements, you are asked to indicate your opinion about all statements.

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Australian Council for Educational Research

Page 2

- 1 Money spent on science is well worth spending.
- 2 Scientists usually like to go to their laboratories when they have a day off.
- 3 I would prefer to find out why something happens by doing an experiment than by being told.
- 4 I enjoy reading about things which disagree with my previous ideas.
- 5 Science lessons are fun.
- 6 I would like to belong to a science club.
- 7 I would dislike being a scientist after I leave school.
- 8 Science is man's worst enemy.
- 9 Scientists are about as fit and healthy as other people.
- 10 Doing experiments is not as good as finding out information from teachers.
- 11 I dislike repeating experiments to check that I get the same results.
- 12 I dislike science lessons.
- 13 I get bored when watching science programs on TV at home.
- 14 When I leave school, I would like to work with people who make discoveries in science.
- 15 Public money spent on science in the last few years has been used wisely.
- 16 Scientists do not have enough time to spend with their families.
- 17 I would prefer to do experiments than to read about them.
- 18 I am curious about the world in which we live.
- 19 School should have more science lessons each week.
- 20 I would like to be given a science book or a piece of scientific equipment as a present.
- 21 I would dislike a job in a science laboratory after I leave school.
- 22 Scientific discoveries are doing more harm than good.
- 23 Scientists like sport as much as other people do.
- 24 I would rather agree with other people than do an experiment to find out for myself.
- 25 Finding out about new things is unimportant.
- 26 Science lessons bore me.
- 27 I dislike reading books about science during my holidays.
- 28 Working in a science laboratory would be an interesting way to earn a living.

Page 3

- 29 The government should spend more money on scientific research.
- 30 Scientists are less friendly than other people.
- 31 I would prefer to do my own experiments than to find out information from a teacher.
- 32 I like to listen to people whose opinions are different from mine.
- 33 Science is one of the most interesting school subjects.
- 34 I would like to do science experiments at home.
- 35 A career in science would be dull and boring.
- 36 Too many laboratories are being built at the expense of the rest of education.
- 37 Scientists can have a normal family life.
- 38 I would rather find out about things by asking an expert than by doing an experiment.
- 39 I find it boring to hear about new ideas.
- 40 Science lessons are a waste of time.
- 41 Talking to friends about science after school would be boring.
- 42 I would like to teach science when I leave school.
- 43 Science helps to make life better.
- 44 Scientists do not care about their working conditions.
- 45 I would rather solve a problem by doing an experiment than be told the answer.
- 46 In science experiments, I like to use new methods which I have not used before.
- 47 I really enjoy going to science lessons.
- 48 I would enjoy having a job in a science laboratory during my school holidays.
- 49 A job as a scientist would be boring.

Page 4

- 50 This country is spending too much money on science.
- 51 Scientists are just as interested in art and music as other people are.
- 52 It is better to ask the teacher the answer than to find it out by doing experiments.
- 53 I am unwilling to change my ideas when evidence shows that the ideas are poor.
- 54 The material covered in science lessons is uninteresting.
- 55 Listening to talk about science on the radio would be boring.
- 56 A job as a scientist would be interesting.
- 57 Science can help to make the world a better place in the future.
- 58 Few scientists are happily married.
- 59 I would prefer to do an experiment on a topic than to read about it in science magazines.
- 60 In science experiments, I report unexpected results as well as expected ones.
- 61 I look forward to science lessons.
- 62 I would enjoy visiting a science museum at the weekend.
- 63 I would dislike becoming a scientist because it needs too much education.
- 64 Money used on scientific projects is wasted.
- 65 If you met a scientist, he would probably look like anyone else you might meet.
- 66 It is better to be told scientific facts than to find them out from experiments.
- 67 I dislike listening to other people's opinions.
- 68 I would enjoy school more if there were no science lessons.
- 69 I dislike reading newspaper articles about science.
- 70 I would like to be a scientist when I leave school.

APPENDIX C

EARTH SCIENCE PRE /POST TEST

Name:
Class Period:

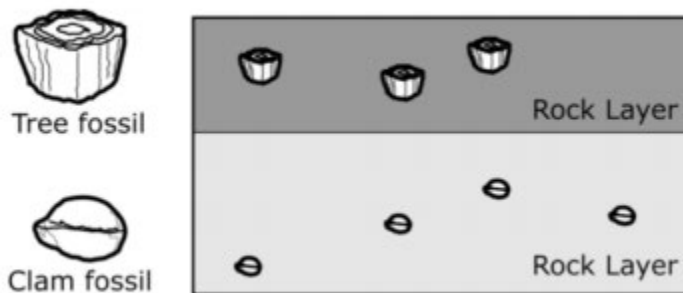
Earth History

Short Answer

1. When examining rock layers, where do you find the oldest material?

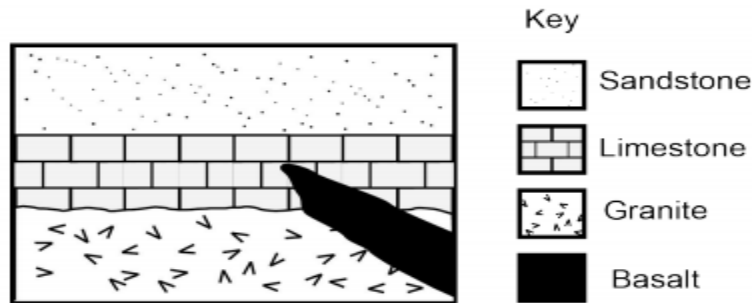
2. Why is a geologic time scale helpful for describing the Earth's history?

3. Fossils of trees were discovered in a sedimentary rock layer, and in a rock layer below were fossils of clam shells. Based on this evidence, what conclusion can be made about the sequence of climates in the past in the area where the fossils were discovered?



Multiple Choice:

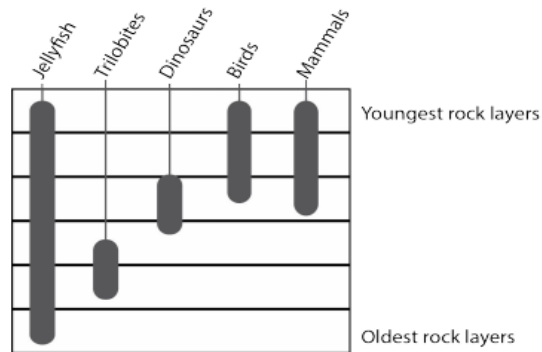
1. The illustration provided shows three rock layers and an intrusion of basalt. When molten rock pushes its way into rock layers already formed, it creates an intrusion.



The rock strata indicate that the basaltic intrusion must have occurred—

- a. After the limestone was deposited
- b. Before the granite was formed.
- c. After the sandstone was deposited
- d. Before all three layers were formed

2. The diagram here provides information on when fossils of certain organisms are found in the fossil record.



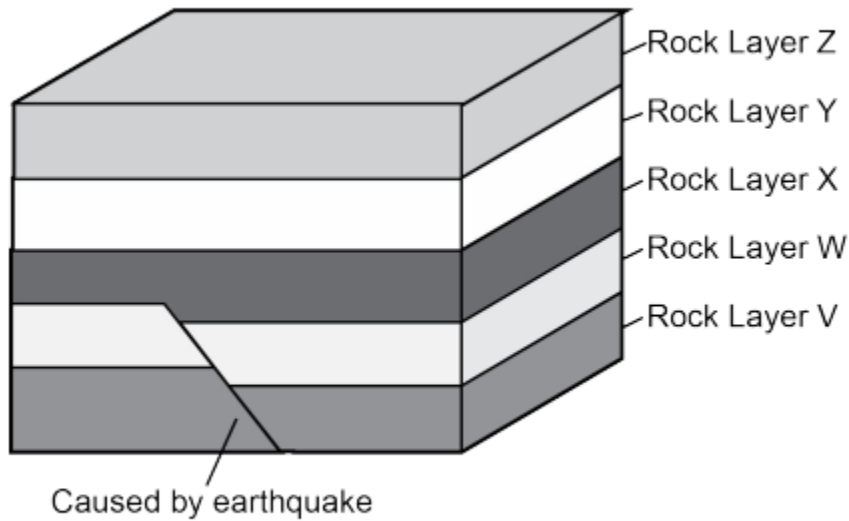
Which of the following conclusions can be drawn from the data in this diagram?

- Jellyfish and trilobites never competed for resources
- Trilobites and dinosaurs did not live at the same time
- Most mammals are in competition with birds for resources
- Mammals did not appear until after the dinosaurs went extinct

3. The fossil remains of organisms with skeletons are not found in the lowest layers of rock discovered. How is the lack of fossilized skeletons in the lowest rock layers best explained?

- Organisms with skeletons did not evolve until after these rock layers formed.
- The fossils of organisms with skeletons are only found in the oldest rocks.
- Fossil skeletons are usually crushed if other rock layers are about the ones they are in.
- Organisms with skeletons live only at the highest altitudes, which is where they turn to fossils

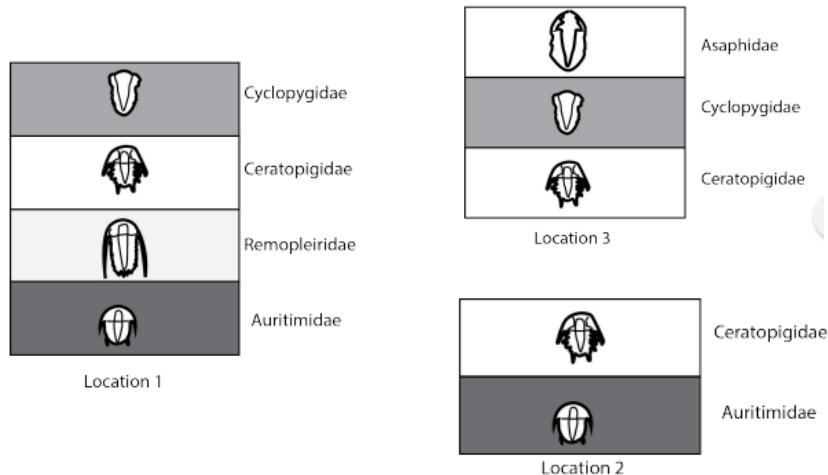
4. The illustration here shows rock layers in their original order, along with a fracture in some rock layers caused by an earthquake.



Based on the evidence in the illustration, an earthquake occurred—

- Before layer W was deposited
- Before layer X was deposited
- After layer Y was deposited
- After layer Z was deposited

5. The illustration shows rock layers from three different locations and fossils the rock layers contain. The fossils are all trilobites, ancient organisms that were different over time.



- The trilobite Cyclopygidae appeared most recently of those shown here
- The trilobite Ceratopigidae appeared before all the others
- The trilobite Remopleiridae is the oldest of all the trilobites
- The trilobite Asaphidae appeared most recently of those shown here

APPENDIX D

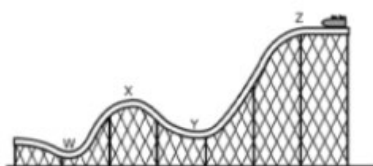
POTENTIAL AND KINETIC ENERGY PRE /POST TEST

Name:

Class Period

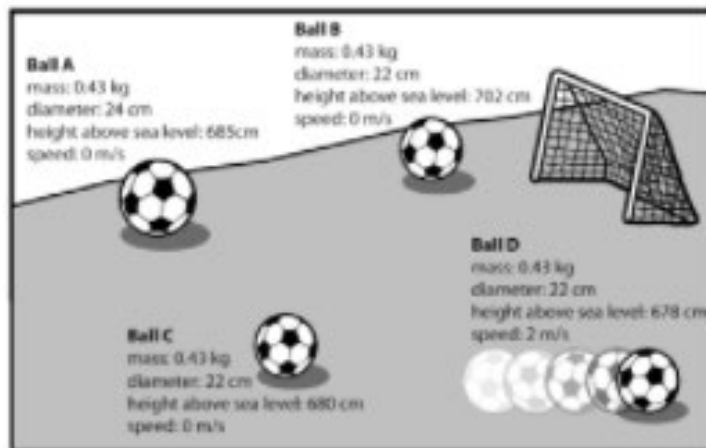
Potential Energy Post Test

1. The illustration shows a roller coaster and indicates four different positions the car might be at as it moves along the track. Identify at which point in the roller coaster's journey does it have the least potential energy and explain why.

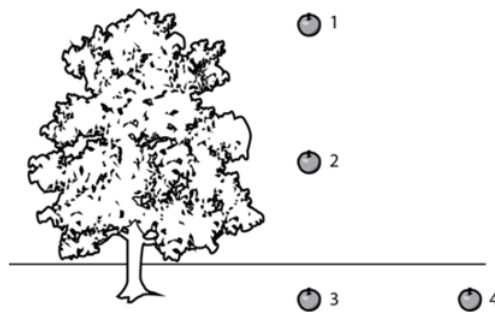


2. A truck is parked at the bottom of a hill. It moves from the bottom of a hill and parks at the top. How does the truck's potential energy when it is at the bottom of the hill compare to its potential energy when it is at the top of the hill?

3. The image here shows four soccer balls at four different locations on an uneven soccer field very near sea level. Which soccer ball has the greatest amount of potential energy and why?



4.

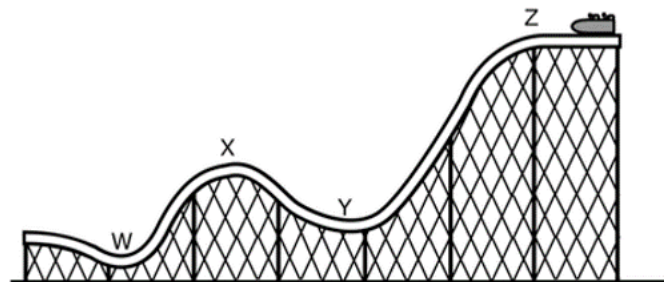


At which position on the diagram would an apple have the greatest potential energy?

- A. Position 1
- B. Position 2
- C. Position 3
- D. Position 4

5.

An illustration of a roller-coaster is provided.



At which point in the roller-coaster's journey along the track does it have the greatest potential energy?

- A. Position Z
- B. Position Y
- C. Position X

D. Position W

Students conduct an experiment using a toy car with the mass of 10g, a toy car with the mass of 20g, and a toy car with the mass of 30g. The students want to test the cars on a ramp and measure how far the cars traveled. Evaluate the information and determine the question they are trying to test with this experiment.

6.

- A Does the height of the ramp influence the amount of potential energy?
- B Does the mass of the car influence the amount of kinetic energy?
- C Does the amount of incline determine how far the car will travel?
- D Does the mass of the object influence the amount of potential energy?

7

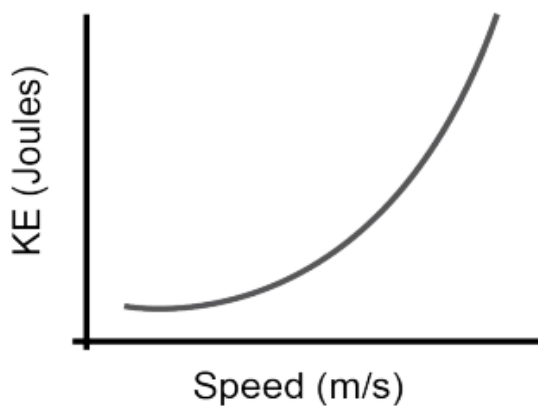
A student creates a ramp by stacking four blocks and then leaning a meter stick against it. She releases four different balls from the same position on the ramp and calculates their speeds.

Type of Ball	Mass (g)
Golf	46 g
Tennis	57 g
Baseball	145 g
Softball	198 g

Based on the information in the table above, which ball would you predict to have the least kinetic energy when it reaches the end of the ramp?

- A. Golf Ball
- B. Tennis Ball
- C. Baseball
- D. Softball

8. A graph showing the kinetic energy and speed of a moving object is provided.



Which of the following can be concluded from the graph?

- A** Kinetic energy only changes when speed changes.
- B** Speed is only related to the size of an object.
- C** Kinetic energy increases as speed increases.
- D** All moving objects have the same kinetic energy.

APPENDIX E

WASHBURN PHENOMENON SURVEY

Phenomenon 3D Assessment Survey

Please note that participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. Thank you!

* Required

Email address *

Your email

I consider myself a strong science student *

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Agree
- ☐ Strongly agree

I know how what I am learning in science connects to life outside this classroom *

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Agree
- ☐ Strongly agree

I feel engaged in science class *

1 2 3 4 5

I can see how one day's lesson is connected to the next *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

I feel confident about applying my science learning in my assessments *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Agree

When I read the assessment questions I felt confident in understanding what the questions were asking me to do

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

I feel my assessments test what I know *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

Thinking about the unit phenomena helps me understand what I am learning *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

I like having a theme or phenomena with our units *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

Which best describes you in science class? *

- ☐ I frequently ask questions/raise my hand
- ☐ I listen attentively but do not often speak unless called upon
- ☐ I pay attention but I try not to be noticed or called upon
- ☐ I do not sit in my seat and often talk to my peers and am off task

Is there anything about science class you would like to tell me?

Your answer

SUBMIT

APPENDIX F

WASHBURN PHENOMENON INTERVIEW QUESTIONS

Interview Questions

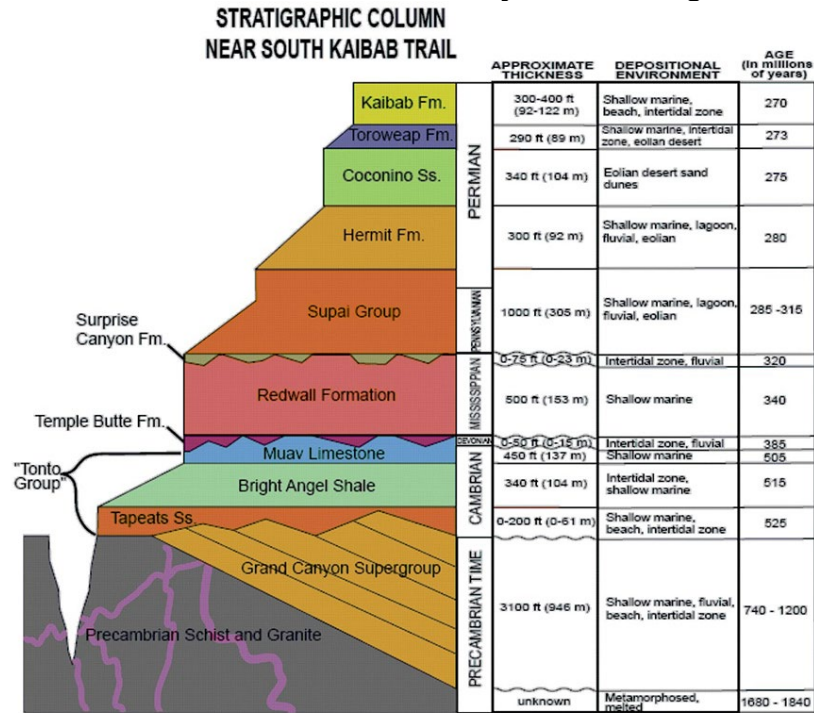
Participation in this study is voluntary and participation will not affect a student's grade in any way.

1. What do you like about science?
2. What do you think about the tests in science? How are they similar or different from the tests you have taken in the past?
3. How does our current unit relate to your life outside of school?
4. Which of these Science and Engineering Practices do you feel are using?
5. What helps you feel confident about your learning in science class?

APPENDIX G

GRAND CANYON CLAIM EVIDENCE REASONING

Prompt: What can we learn about Earth history from looking at the Grand



Canyon?

Claim: The Grand Canyon can tell us about the past organisms and climate of the location and using the Law of Superposition about the age of the rocks

Evidence: Provide data from the picture above

Evidence 1	
Evidence 2	

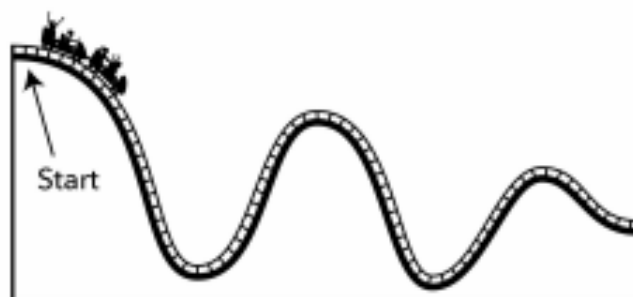
Reasoning: Tie the evidence together with scientific principles we have learned about

APPENDIX H

POTENTIAL AND KINETIC ENERGY CLAIM EVIDENCE REASONING

Scenario

Keshaun and Myra went to the amusement park last summer. They noticed that the roller coaster was slower on the way up but went fast as they were on the way down. Keshaun's favorite part was the first drop, but Myra liked when they were going a little slower.

External Data**Prompt**

Write a scientific explanation that explains when the roller coaster has the most kinetic energy.

Claim:

Evidence:

Reasoning:

APPENDIX I

STEMSCOPES CLAIM EVIDENCE REASONING RUBRIC



Claim-Evidence-Reasoning

Rubric for Writing a Scientific Explanation

Points Awarded	2	1	0
Claim	Not applicable.	Answers the question and is accurate based on the data.	No claim or does not answer the question.
Evidence	Cites data and patterns within the data, and uses labels accurately.	Cites data from the data source but not within the context of the prompt.	No evidence or cites changes but does not use data from the data source.
Reasoning	Cites the scientifically accurate reason using correct vocabulary and connects this to the claim. Shows accurate understanding of the concept.	Cites a reason but it is inaccurate or does not support the claim. Reasoning does not use scientific terminology or uses it inaccurately.	No reasoning or restates the claim but offers no reasoning.
Rebuttal	Rebuttal provides reasons for different data or outliers in the data. Can also provide relevance to the real world or other uses for the findings.	Rebuttal is not connected to the data or is not accurate.	Does not offer a rebuttal.