STEAM Education in the Middle Grades:

The impact of the Engineering Design Process VS. The Scientific Method in Content Comprehension.

by

Scott Sutherland

Bachelor of Science

Georgia Southern University, 2012

Master of Education

University of South Carolina, 2016

Submitted in Partial Fulfillment of the Requirements
For the Degree of Master of Education in
Teaching
College of Education
University of South Carolina
2016

Table of Contents

Abstract:

My research comparing different curriculum models has confirmed the necessity of using STEAM within a science classroom to promote conceptual understanding of the content. The curriculum inquiry model of teaching science using the scientific method is insufficient to promote academic growth compared to the STEAM curriculum model that utilizes the engineering design process. In my study, I used both curriculum models while teaching two similar physical science units to a group of sixth-grade students. I found out that the STEAM curriculum model utilizing the engineering design process were much more effective in helping students understand the scientific concept. The engineering design process is essential since it reinforces the expanded use of the STEAM curriculum model within science classrooms.

Introduction

Science has become a well-desired key subject area in terms of skills and the critical thinking mindset that comes with applying them (Hart Research Associates, 2013). Even so, fewer students are pursuing scientific studies to become qualified for the high-demand jobs and careers available (Resmovits, 2012). The engagement has always been high in science due to the hands-on nature of the content itself. Still, grades have statistically shown that students struggle academically in science and mathematics. The area of science has been taught using various strategies over the years. Currently, one of the significant trends in teaching science is by also integrating technology, engineering, and mathematics into the subject, which is referred to as STEM (Messinger, 2015). STEM itself stands for science, technology, engineering, and mathematics. The STEAM curriculum model also involves focusing on real-world scenarios that connect the academic content to applications through project-based learning. The engineering design process is slowly replacing the problem-based learning approach used by most science teachers throughout the nation. It focuses on inquiry-based learning through the use of the scientific method (Mills, 2015). The shift from scientific method to engineering design process has been the focus of my action research. STEM has focused on many studies throughout the nation, with very little research focusing on STEAM, including the arts-integrated with STEM components.

This action research study will focus on STEAM as opposed to STEM to include the arts and humanities. I devised the following question for my action research project. This question helped me compare STEAM with the scientific method to focus solely on the academic impacts and how each process aided sixth-grade students in comprehending the standards-based material. To explore this question, I selected one class of 6th-grade science students who have not yet mastered a standard involving different forms of energy.

- What is the impact on comprehension of teaching a 6th grade science lesson using a STEAM based learning approach and the engineering design process compared to an inquiry-based learning approach and the scientific method?

Conceptual Framework

My teaching philosophy involves ideas from several theorists, primarily Jean Piaget's cognitive constructivism theory. Piaget's theory focuses on students overseeing their learning to construct new knowledge from learning experiences. Students in future career applications can then use this newly created knowledge. I feel that students learn best by engaging actively in the content in a hands-on manner that allows them to learn from experience and see the purpose behind their learning. If students do not engage in science content personally and individually, they will disengage from the learning. Learning experiences must incorporate students' interests and aspirations to explore how many content areas such as science, technology, engineering, the arts and humanities, and mathematics can be intertwined. This educational approach, known as STEAM, blends these subject areas in an interdisciplinary way that includes problem-based and project-based learning applications within the classroom. According to Yakman (2008), "STEAM is a developing educational model of how the traditional academic subjects of science, technology, engineering, arts and mathematics can be structured into a framework by which to plan integrative curricula" (pg. 1). This STEAM-based learning approach is the basis of my research. It will be studied to analyze how it compares with other hands-on teaching strategies using the scientific method to achieve the same goal in content comprehension and mastery. The theory being utilized throughout this action research study is cognitive constructivism. "Cognitive constructivism views learning as the process of constructing meaning; it is how people make sense of their experience" (Baker, 2019, p.1). Cognitive constructivism allows students to develop meaning behind their experiences, constructing new knowledge by making sense of the world through active discovery. Active discovery is provided by using the STEAM curriculum model, is it supports students actively finding solutions to real world problems by connecting multiple subject areas to their learning experiences.

Literature Review

Research in teaching science strategies has indicated that hands-on methods, in general, have benefits in terms of academics, engagement, and future interest in science-based careers (Barron & Darling-Hammond. 2008). Grant, Malloy & Hollowell, 2013 focus purely on how student engagement is affected through STEM-based lessons regarding future interest in science-based careers for high school students. Beckett, McIntosh, Byre & McKinney (2011), on the other hand, focus on the educational benefits of STEM in regard to elementary school students, while Hole (2008) focused on the educational benefits of hands-on science methods in general but used a variety of hands-on techniques that include STEM-based instruction. These studies help solidify the impact of STEM-based teaching by noting both academic and motivational-based benefits of using it at different grade levels.

According to a study conducted in 2011 by Beckett, McIntosh, Byrd, and McKinney, STEM-based instruction aided third-grade mathematics students in comprehension of subtraction with regrouping. McIntosh told her students that they would be subtraction detectives, and they were each given base-ten blocks and a magnifying glass. McIntosh then presented problems for students to explore and instructed them to determine if an inversion or upside-down subtraction had been employed. After four weeks of study, McIntosh administered the posttest in which results showed significant gains. The other researchers conducted observations as McIntosh used these strategies within her classroom. The first class attempted an average of 23 additional problems on the posttest, jumping from an average of 49 to 72 attempted while also improving the average percentage correct from 96 percent to 99.7 percent. The second class tried 29 additional problems on the posttest, jumping from an average of 34 to 63 attempted while improving the average percentage correct from 80 percent to 95 percent.

A different study conducted by Hoke (2008) continued this trend of identifying educational benefits by researching the effects on student performance using hands-on activities to teach seventh-grade students' measurement. Various hands-on instructional and curricular models, including STEM, were utilized to investigate different measurement Concepts. Each activity spanned over two to four days to complete. The study found only five out of twenty-six students received scores lower than an average of 70%. However, gains were still made by these students across the class.

Finally, a third study conducted by Grant, Malloy, and Hollowell (2013) researched enhancing students' interest in science and technology through cross-disciplinary collaboration and active learning techniques. The researcher provided a cohort of 29 students with opportunities to increase their insight into and appreciate the investigative process by connecting science and technology to their daily lives during a 4-week summer program. These students, in turn, used active and collaborative learning to research and address the real-world problem of obesity. Survey data from the end of the summer indicated that 68.1% of students planned to pursue a major in STEM.

Very little research exists in STEAM instruction regarding the educational benefits of helping students learn the standards-based material more effectively than other hands-on techniques. This fact aids in my research to compare these different hands-on instructional strategies specifically for the middle grades. According to Tenaglia (2017), "a STEAM curriculum framework is a solution to the need for more creative, innovative thinkers in the workforce" (pg. 9). This statement supports the fact that more research needs to be conducted as to why STEAM needs to be utilized more in science classroom.

Context of the Study

A mixed-methods action research study was conducted. This study included nine participants as students learned about two different forms of energy within 6th-grade science. The study was conducted over two weeks and focused on outcomes related to two other teaching techniques: (1) a *STEAM-based curriculum approach using the engineering design process, and (2) an inquiry-based curriculum approach using the scientific method.* The participants for this study were nine sixth-grade science students attending a Title 1 public school in the Southeastern United States. The school that the participants participate in consists of grades six through eight and has one hundred and sixty-seven students. Five of the participants come from lower socio-economic households near the poverty line, while four come from lower-middle-class families. Four of the participants are male, and the other five are female; five are Caucasian, and the other four are African American. All participants have average standardized test scores across several subject areas. I chose this particular class of students for the study because of the relatively equal number of male to female students and Caucasian to African American students. I wanted to ensure that data reflected a diverse classroom.

Data Collection

From September 5th, 2016, to September 19th, 2016, I conducted daily observations of the students through inquiry-based labs using the scientific method and engineering challenges using the engineering design process. I focused these observations on both student engagement in the task and the academic understanding that the students displayed through their responses and reflections to discussion questions recorded within their interactive lab notebooks. I embedded these discussion questions within their inquiry labs and engineering challenge handouts. I used the discussion questions to analyze student thinking to apply critical concepts within the science standards correctly. I also kept a logbook during this time to record how individual students and student groups could answer probing questions that focused on essential knowledge from their activities. I used these observations to analyze student understanding of content using the scientific method compared to the engineering design process. As a researcher, I expected that the students' answers within their notebooks reflected an understanding of the content in their own words.

On September 5th, 2016, all participants were administered a pretest over the first concept involving mechanical energy and compared this with a post-test issued on September 9th, 2016. On September 12th, all participants were administered a pretest over the second concept involving electrical energy and compared with a post-test distributed on September 16th, 2016. These summative assessments were all administered on computers with student participants using the program USATestPrep. I chose assessment items from an item bank included on USATestPrep that aligned with national science standards and involved various questions, including multiple-choice and performance tasks. Each of the nine participants was also individually interviewed about the two processes they used to learn about two different forms of energy. I recorded the students' responses within a logbook during each interview. I tallied the students' responses to analyze how many felt they learned more effectively using the scientific method and how many participants thought they knew more effectively using the engineering design process.

Questions included the following:

1. Which process helped you learn about energy better, the scientific method or the engineering design process?
2. Why was that particular process more helpful to you?
3. Why was the other process not as helpful to you?

Data Analysis

I collected data for my entire class across all these methods and the analysis of the data focused solely on the small group participating in the study. The qualitative data, composed of the interviews and teacher documented notes within the logbook, were more closely analyzed to identify trends and patterns related to content comprehension of the material during each of the two weeks. This process helped me determine the academic impacts of using the engineering design process compared to using the scientific method when teaching about two different forms of energy in the 6th grade.

To accurately analyze the quantitative data, which consisted of pre and post-test scores, I recorded the results of each on a digital spreadsheet that differentiated between each question number and content section. I used this information to create several charts and graphs for both the pre and post-test. These charts and graphs include: An academic growth comparison between the two units, a score comparison between the pre and post-test of the unit over mechanical energy taught using the scientific method and an inquiry-based curriculum approach, and a score comparison between the pre and post-test. I used these data to compare growth between pre and post-tests of each unit to analyze each teaching method's effectiveness over the two weeks.

Data and Results

<u>Finding 1:</u> Students' comprehension of the content increased when I used a STEAM-based curriculum approach.

<u>Finding 2:</u> Students retained information at a higher rate due to the open exploration and flexibility of steps involved with STEAM and the engineering design process.

I obtained the following results concerning the students' pre and post-test scores for each curriculum approach. I collected the first data set before and after teaching the unit involving mechanical energy, conducted using the scientific method and an inquiry-based curriculum approach.

Table 1: Pre and Post Test Scores and Amount of Academic Growth from Mechanical Energy Unit

Student	Pre-Test Score	Post-Test Score	Amount of Academic Growth	
A	55%	60%	+5 Points	
B	50%	65%	+15 Points	
C	45%	45%	None	
D	85%	80%	-5 Points	
E	75%	75%	None	
F	65%	50%	-15 Points	
G	40%	50%	+10 Points	
H	45%	70%	+25 Points	
I	50%	45%	-5 Points	

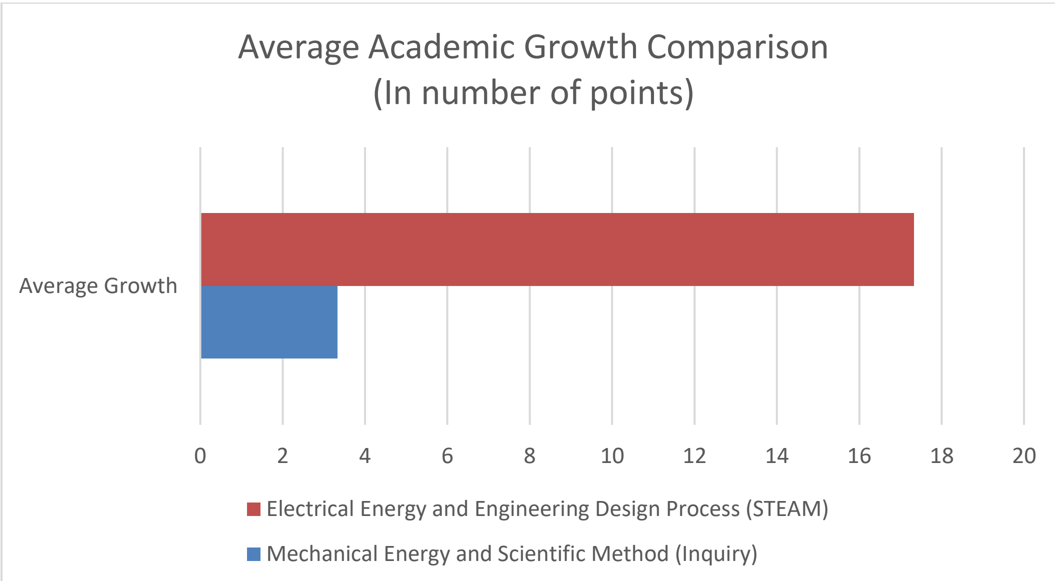
I collected the second set of data was before and after teaching the unit involving electrical energy, which involved using the engineering design process and a STEAM-based curriculum approach.

Table 2: Pre and Post Test Scores and Amount o Academic Growth from Electrical Energy Unit

Student	Pre-Test Score	Post-Test Score	Amount of Academic Growth	
A	56%	81%	+25 Points	
B	69%	94%	+25 Points	
C	50%	69%	+19 Points	
D	63%	88%	+25 Points	
E	56%	75%	+19 Points	
F	31%	56%	+25 Points	
G	63%	50%	-13 Points	
H	50%	69%	+19 Points	
I	38%	50%	+12 Points	

According to the data collected from assessments, 78% of the participants learned the content more effectively when I used the engineering design process and a STEAM-based curriculum approach. Seven out of nine students had more academic growth when I used the STEAM-based curriculum approach and engineering design process. Two students had more academic growth when I used the inquiry-based instructional practice and the scientific method. The other thing is that more students grew, but growth was more significant.

<u>Figure 1</u>: *Average Academic Growth Comparing the Electrical Energy Unit and Mechanical Energy Unit*



I collected the following data with daily observations of the participants as they progressed through each instructional unit. The following is an outline of what was done each day along with observations recorded for how each of the participants engaged in the activity and each of their levels of mastery when answering questions related to the content.

<u>Mechanical Energy</u>: Taught using the scientific method and an inquiry approach.

On the first day of this study, a pre-assessment was administered to students to gauge their level of comprehension as it related to the concept of mechanical energy. On day two, twelve total students were divided into four groups, including the nine participants. I tasked students with investigating how the two types of mechanical energy, potential and kinetic, change with different objects based on their mass, height, and velocity. Students used balances, meter sticks, and timers to collect data comparing golf balls and ping pong balls. All nine participants were engaged but had difficulty following step-by-step instructions involved in the scientific method.

One group of three participants did not finish the investigation involving students D, F, and I. On day 3, I observed that there was minimal content retention from the previous day's investigative lab as the remaining group of three participants finished. Six out of nine participants could not answer discussion-based questions presented by the teacher involving the content and post-lab conclusion questions located on their handouts. These students included A, C, D, E, F, and I. On day 4, students were divided into pairs of two/three for a second investigation involving the content. Students investigated the impact of height and velocity on skaters determining their total mechanical energy with a virtual lab. The lesson engaged all participants, but three out of the four pairs had difficulty following step-by-step procedures using the scientific method involving students A, C, D, E, F, and I. Six out of nine participants could not answer discussion-based inquiry questions presented by the teacher regarding the content and post-lab inquiry conclusion questions on their handouts. These students included A, C, D, E, F, and I. Finally, on day five, a post assessment was administered to students to gauge their final level of comprehension at the end of the mechanical energy unit.

<u>Electrical Energy</u>: Taught using the engineering design process and a STEAM approach.

On the sixth day of this study, a pre-assessment was administered to students to gauge their level of comprehension as it related to the concept of electrical energy. On day seven, twelve total students were divided into four groups, including the nine participants. I gave students the engineering problem of designing a circuit that could power four different light fixtures using only one power source within an office hallway. Students used multi-meters and other electrical equipment to explore ways to solve this problem. All nine participants were engaged in using the engineering process and had little to no confusion on what to do. Three groups, including five participants, did not finish the engineering challenge involving students C, G, E, H, and I. On day eight, I observed that there was high content retention from the previous day's engineering challenge, as the remaining three groups of five participants finished. One out of nine participants, student G, could not answer discussion-based questions presented by the teacher involving the content and post-lab conclusion questions located on their handouts. I overheard Student F saying to her group, "I learned so much better this way!" On day nine, I divided students into pairs of two/three for a second engineering challenge involving the content. Students had to design a new circuit for the office building that utilized solar panels as a power source instead of batteries. Additionally, they had to provide data on the best angle of position for the solar panels in the top of the office building that would help to generate the most electrical power. None of the participants had any difficulty following the engineering design process, and all were engaged. Only one out of nine participants could not answer discussion-based questions presented by the teacher involving the content and post lab conclusion questions located on their handouts, which was student G. Everyone else was performing high. Finally, on day ten, a post assessment was administered to students to gauge their final level of comprehension at the end of the electrical energy unit.

Conclusion

Based on the data analysis, the STEAM curriculum model is more effective at facilitating the teaching of science content when compared to the inquiry curriculum model. Most students enjoyed the flexible nature of the engineering design process involved with the STEAM curriculum model, which was not as dependent on following step-by-step procedures. At the end of the unit involving the scientific method and an inquiry-based approach, 33% of the participants answered discussion questions presented by the teacher and post-lab conclusion questions located in their handouts. At the end of the unit involving the engineering design process and a STEAM-based approach, 89% of the participants answered discussion questions presented by the teacher and post-lab conclusion questions located in their handouts. Multiple data, including a pre/post assessment and observations, were used to account for the fact that there were two different units used in this study. I used observations to gauge both student comprehension of the content before teaching and engagement in the content itself. Based on pre-assessment data, individual students' understanding of the two units was similar before I used the instructional strategies. Observations also noted that student engagement was identical between each of the units. I want to point out that it is not quite comparable because they are two different units. Data were collected using student interviews at the end of the two weeks of teaching and compiled together to display their answers to each question. I expressed this data in appendix d, table 4.

Eight of the nine participants indicated they liked using the engineering design process using a STEAM-based curriculum approach, more than using the scientific method, which I taught using an inquiry-based curriculum approach. Many of the same themes came up from student to student, including that they liked the flexibility provided with STEAM and the engineering design process compared with a more orderly series of steps provided with inquiry and the scientific method. Exploring the content to solve an engineering problem with STEAM was another recurring theme that many students indicated made learning the content less confusing. This process allowed the students to interact with and understand the content in a more facilitative manner, promoting open exploration.

These findings have helped answer the research question on the impact of teaching a 6th-grade science lesson using a STEAM-based learning approach and the engineering design process compared to an inquiry-based learning approach and the scientific method. STEAM, utilizing the engineering design process, seemed to provide an easier-to-follow model of learning the content for the participants. This curriculum model helped by allowing for more personal exploration of the content, flexible steps that did not go in a specific order, and a real-world problem that helped boost understanding of the purpose behind the engineering design process. Additionally, the engineering design process used during the unit has real-world content applications.

Limitations of Research

Since two different units were involved, one being taught using each of the two curriculum models, it may be difficult to say for certain that a unit itself was simply not more difficult. However, qualitative observations were included to back up the quantitative pre and post test data to support that it was the curriculum model which made a difference in students' comprehension of the content. Additional studies will need to be conducted to better conform this conclusion to rule out the possible limitations mentioned. Since the goal of action research is not to draw generalizable conclusions that apply to the larger population, the results if this study are specific to the group of students involved.

Implications for Teaching

This research aimed to determine which curriculum model provided students with a better means to learn the academic content. This research looked at comparing the STEAM-based curriculum model using the engineering design process with the inquiry-based curriculum model using the scientific method and how they impacted academic performance. Based on the data, I will continue to use the STEAM-based curriculum model with more of my lessons to succeed. This model gave students more freedom to learn how to solve real-world problems by working collaboratively to develop unique solutions. Having the qualitative data to support the quantitative data with reasons for why it was more effective was an excellent way to pinpoint critical evidence to support the continuing of this curriculum model within science education. I learned that the concrete nature of the scientific method was counterproductive and confused most of the students who were participants in the study. On the other hand, the more fluid nature of the engineering design process made learning the material more student-driven and resulted in many different solutions to the engineering problem. This process resulted in the students learning the content through meaningful experiences, which greatly aided in content comprehension. While the goal of action research is not to generate generalizable knowledge, the results on this study can be used to promote other teachers and curriculum developers to consider how a STEAM curriculum approach may impact their own content areas to support students' comprehension.

Implications for Future Research

One main goal of this action research study was to determine if content comprehension is impacted by using the STEAM curriculum model compared to the scientific method. There has been a lot of research on the engagement factor of STEAM at different grade levels, so I wanted to find out if it impacted academics as well. Since the findings indicated a large difference in the academic growth comparison, the educational community could benefit significantly through future research on this topic. Based on the results, several implications for future research exist, including if a larger sample size will impact the results, if a particular demographic would benefit more or less, if similar results occur with other science standards, and what the results would be if the same unit is taught using the different curriculum models across multiple classes. However, based on this mixed methods action research study alone, I can conclude that the STEAM curriculum model was more effective with this specific group of students.

References

Baker L, Ng S, Friesen F. Paradigms of Education. An Online Supplement. [Internet]. 2019. Available from www.paradigmsofeducation.

Barron, B. & Darling-Hammond, L. (2008). *Teaching for meaningful learning* [PDF file] Retrieved from *http://www.edutopia.org/pdfs/edutopia-teaching-for-meaningful-learning.pdf*

Beckett, P., McIntosh, D., Byrd, L. & McKinney, S. (2011). *Action research improves math instruction* [PDF file] Retrieved from: *http://www.fimcvi.org/wpcontent/uploads/2011/12/NCTM-Action-Research-Article.pdf*

Grant, D., Malloy, A. & Hollowell, G. (2013) Enhancing students' interest in science and technology through cross-disciplinary collaboration and active learning techniques. *Journal of Information Technology Education: Volume 12, 2013*

Hart Research Associates (2013). It takes more than a major: Employer Priorities for College Learning and Student Success. Retrieved from: *https://www.aacu.org/sites/default/files/files/LEAP/2013_EmployerSurvey.pdf*

Hoke, D. (2008). Effects on student performance of using hands on activities to teach seventh grade students measurement concepts. *http://etd.fcla.edu/CF/CFE0002228/Hoke_Darlene_M_200807_MAST.pdf*

Messinger, E. (2015). Education Trends: The STEM Effect. http://www.newyorkfamily.com/education-trends-the-stem-effect/

Mills, H. (2015). What Happened to the Scientific Method? http://corelaboratewa.org/theres-no-scientific-method/

Resmovits, Joy (2012). Youth unlikely to pursue science, technology, engineering jobs, survey finds. *Huffington Post*. Retrieved from: *http://www.huffingtonpost.com/2012/01/25/science-technology-engineering-math-survey-mit_n_1229089.html*

Tenaglia, Taryn, "STEAM Curriculum: Arts Education As An Integral Part Of Interdisciplinary Learning" (2017). Graduate Education Student Scholarship. 11. https://mosaic.messiah.edu/gredu_st/11

Yakman, G. (2008). ST∑@M Education: an overview of creating a model of integrative education. Virginia Polytechnic and State University.

Appendices

(Please see the following pages)

Appendix A: Handouts Used During Days 2 and 3 of Mechanical Energy Unit

Mechanical Energy Lab

Introduction

What you can find is that Potential Energy and Kinetic Energy are some of the most common types of energy you will find in the world. In this lab, you will be observing the effects of potential energy and kinetic energy as they are applied with mechanical energy.

Pre Lab

1. What is the definition of Kinetic Energy? Draw a picture demonstrating Kinetic Energy, and draw an arrow showing where the force would be observed.

2. What is the definition of Potential Energy? Draw a picture demonstrating Potential Energy, and draw an arrow showing where the energy would be observed.

Materials (per group)

Meter Stick
Golf Ball
Pocket Calculator*
Ping Pong Ball
Masking Tape*

Safety

Put on safety glasses while conducting the experiment, though chemicals and heat aren't being used, safety is a concerned that should be practiced.

Procedure

Part 1 Kinetic Energy

1. Begin by going to a scale located on one of the side counters and obtain the mass of the ping pong ball and obtain the mass of the golf ball. Record the masses below

   Mass of Ping Pong Ball _________ Mass of Golf Ball _________

2. Next go to a table that belongs to one of your group members. Make sure the table is cleared off and place both the ping pong ball and golf ball on the table.

3. Take turns rolling the golf ball on the table and pass it between your hands for 20 to 30 seconds. Try changing the speed of the ball so it passes to each hand real fast or real slow. After you finish rolling the golf ball on the table, take turns rolling the ping pong ball back and forth for 20 to 30 seconds. Write down your observations about how the ball felt when it touched the palm of your hands in the data table below.

Part 2 Potential Energy

1. Begin by having your meter stick straight up so that the lowest number is on the ground. Find the middle point of the meter stick, this will be the distance of Point 1, Record it below. Next pick a point halfway above (point 2) and below (point 3) of the Point 1. Record the numbers below. (you may grab masking tape and wrap one layer around each of your marked heights).

   Point 1's height ________ Point 2's height ________ Point 3's height ________

2. Next grab your golf ball and line the bottom of the ball to Point 1 on your meter stick. You will now drop the ball and after its first bounce, you will record the height it travels back up from the ground. Perform three trials of this experiment, record it, and obtain the average below Record the data in the table below. Repeat step two for each of the different points on the meter stick.

Data Analysis
Part 1 - Kinetic Energy

Golf Ball Slow	Golf Ball Fast	Ping Pong Ball Slow	Ping Pong Ball Fast

Part 2 - Potential Energy

Point 1 Drop	Point 2 Drop	Point 3 drop
Trial 1	Trial 1	Trial 1
Trial 2	Trial 2	Trial 2
Trial 3	Trial 3	Trial 3
Average	Average	Average

Conclusions

1. What trend did you observe when you conducted the kinetic energy portion of the lab? How does speed or mass affect kinetic energy?

____
____
____

2. What did you notice about the height difference when conducting the potential energy portion of the lab? Which one of the points had the most and the least? Explain your answer.

____
____
____
____
____

3. When conducting part 2 of the lab, were you only observing potential energy? If so explain your answer.

____
____

Hand-out was adapted from https://phet.colorado.edu/

Appendix B: Handout Used During Day 4 of Mechanical Energy Unit.

Mechanical Energy: Potential VS. Kinetic

Intro

In this simulation we will be investigating the relationship between kinetic energy, potential energy, thermal energy, and total energy regarding springs.

1. Click on the link: http://phet.colorado.edu/en/simulation/mass-spring-lab
2. Click the "Play with Sims" button.
3. Click "Physics" > "Masses and Springs"
4. When you see this, click "Run Now!"
5. Switch between this document and the simulation "Masses and Springs" to complete this activity.

Explore

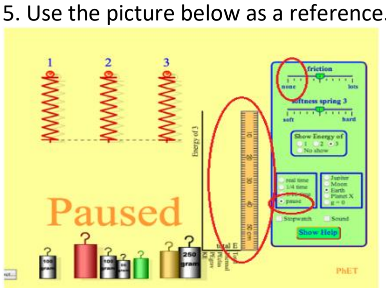
Take 5 mins and freely explore the simulation.

Close the sim and open it again.

1. When you open the activity, click "3" in the "show energy of" box.
2. Slide friction to "none"
3. In the bottom left box, click "pause".
4. Place the Yellow weight onto spring 3.
4. Use the provided ruler, move it to the energy meter.

(***keep in mind, ruler is upside down**, so: 50 =10, 40 = 20, 30 = 30, 20 = 40, 10 = 50, top = 60)

5. Use the picture below as a reference.



Using the ruler to measure:

What is the energy of PEgrav?

What is the total energy?

Now, press 1/16 time and watch what happens.

Explain

Energy

1. what did you notice?

2. As the mass moves down, what happens to KE? PE elas? Total?

3. At what point in the motion is **KE** at its greatest value? Least? (use words: **TOP, BOTTOM, MIDWAY**)

Greatest	
Least	

4. At what point in the motion is **PEgrav** at its greatest value? Least? (use words: **TOP, BOTTOM, MIDWAY**)

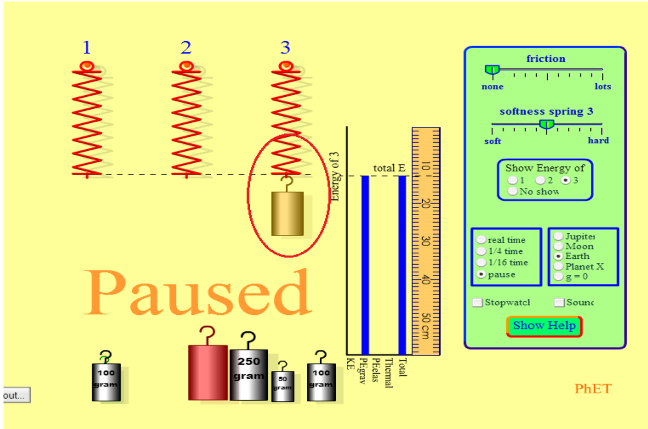
Greatest	
Least	

5. At what point in the motion is **PEelas** at its greatest value? Least? (use words: **TOP, BOTTOM, MIDWAY**)

Greatest	
Least	

Total Energy

Press pause and move the yellow object back to the **neutral position** on spring 3.



Press 1/16 time.

Pause the sim midway as the mass **moves DOWN**.

Use the ruler to find the totals of:

KE ______

PEgrav ______

PEelas ______

Total ______

Pause the sim midway as the mass **moves UP**.

Use the ruler to find the totals of:

KE ______

PEgrav ______

PEelas ______

Total ______

Gravity

1. With the sim still paused, change the gravity to: Jupiter, Moon, Earth, Planet X, and g=0.

2. What effect does gravity have on energy values?

3. Which values increase or decrease?

4. Rank them in order from greatest total energy to least total energy.

a. b. c. d. e.

5. How can you explain this phenomenon?

Apply

1. If total energy were not a meter in the sim, how could we find the value of total energy?

Hand-out was adapted from https://phet.colorado.edu/

Appendix C: Handouts Used During Days 2, 3, and 4 of Electrical Energy Unit.

Engineering Challenge Student Documentation Form	
Student Name (s):	School: ___________________________________ Grade Level: ____________________ Teacher: __________________________________
Define Problem Use the space below to briefly describe the problem that needs to be solved	
Criteria Describe the requirements for solving the problem	
Constraints Describe the limitations for solving the problem	
Research Sources Use appropriate formatting to cite all resources	
Research Summary Summarize the background research that will be used to solve the problem	
Design/Solution Ideas Summarize your ideas for solving the problem and include models if applicable Include specific research that supports your idea and reasoning	
Design Proposal Include a scale drawing and description including materials needed for the design/solution	

Construction Document the processes for constructing your design/solution Include specific details about challenges and solutions used to address challenges
Testing Describe the testing procedures and results Data from testing should be included
Modifications Describe the modifications made to your design/solution Include evidence from your testing and research that supports the need for these modifications
Conclusion/Reflection Summarize the success of your design using evidence from data and research Present strong arguments using evidence and data to support the success of the proposed solution

Appendix D: *Table 4: Student Interview Responses*

Student	Which process helped you learn about energy better, the scientific method or the engineering design process?	Why was that particular process more helpful to you?	Why was the other process not as helpful to you?
A	Engineering Design Process	"I could start at any point in the process and do steps out of order with more flexibility."	"Had to do every little detail, which felt like a lot of extra work."
B	Engineering Design Process	"Did not have to go in a certain order."	"Did not like all the steps and that I couldn't get out of order."
C	Engineering Design Process	"By showing me and allowing open exploration of the topic."	"It took a while and was harder to understand."
D	Engineer Design Process	"I had a lot more freedom and could do things my way in order to find a solution."	"There were just too many specific steps, I felt like I could not really explore more openly."
E	Engineering Design Process	"I liked that there were not really specific steps, but more of a process that guided me."	"I felt like many steps were unnecessary and that I couldn't explore more."
F	Engineering Design Process	"I got to do more with the content since there wasn't ordered steps."	"I did not like how it was in a specific to follow order."
G	Engineering Design Process	"I understood it better, it was less confusing."	"It was more confusing, too many steps."
H	Scientific Method	"I liked the step by step process, it helped me organize by thoughts."	"Without steps, I got confused."
I	Engineering Design Process	"I liked being able to figure stuff out myself."	"It was harder to understand and didn't give the opportunity to explore as much."