April 2020

Engaging Students in Energy Related Topics Using Contextualized Lessons in Physics

Thomas A. Young
Worcester Polytechnic Institute

Repository Citation
-

Engaging Students in Energy Related Topics Using Contextualized Lessons in Physics

A Major Qualifying Project

Submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

DEGREE OF BACHELOR OF SCIENCE

By:
Thomas Young

May 2020

Abstract

The goal of this project is to design curriculum for secondary level (i.e. high school) physics that will lead to increased student engagement with energy related concepts and, in turn, more student interest and performance in energy-related STEM topics. It has been shown that lessons which engage students lead to better understanding and knowledge retention among students. In order to promote student engagement, these lessons are designed to be delivered in contexts such as clean and renewable energy, climate change, and life sciences. This project proposes a model to test whether the delivery of these contextualized lessons will lead to increased student performance as measured through various forms of assessment.

Contents

Acknowledgements

I would like to thank my Advisors, Professors Lyubov Titova and Katherine Chen for their ongoing support of both to this project and to my undergraduate experience. This project would not have been possible without their guidance and valuable input.

I would like to acknowledge the staff and students from the Girls, Inc. Eureka! Program as well as the students and faculty from the REU Site: Developing a Clean Energy Future with Underserved Students at WPI, NSF DUE Award 1852447

I would like to acknowledge the National Science Foundation for the funding of the REU Site: Developing a Clean Energy Future with Underserved Students at WPI

1 Introduction

In this project, several lessons have been designed to compose a unit to teach secondary school physics students about energy-related concepts. This unit emphasizes contextualized learning in formal and informal settings to inform students about energy, its importance in human society, and the need for science-based solutions to the climate crisis. The goal of this project is to design curriculum that will lead to more student interest in topics in physics, as high school physics coursework has been demonstrated to have the strongest correlation of all high school subjects with attainments of a degree in Science, Technology, Engineering and Mathematics (STEM) (Feder, 2011). Our motivation for using energy and climate as a context for physics learning is two-fold. First, climate crisis is a relevant and effective context for engaged learning. Over the past several years we have seen teenagers becoming passionate advocates for the environment, as evidenced by the world-wide Climate Strike actions (climatestike.net). Recent study has also demonstrated that middle and high school students who learn about climate change at school are able to relay this knowledge to their parents and influence their attitudes via intergenerational learning (Lawson et. al, 2019). Second, the STEM jobs in sustainable energy sector have some of the fastest growth, increasing at nearly 6% annually since 2012 (Department of Energy). Our goal is to encourage students, especially students from groups that are traditionally under-represented in STEM disciplines, to pursue those careers. We strive to empower them by fostering deep understanding of physics as a building block for a range of STEM disciplines.

The objectives of this project are to create 4 lessons of physics curriculum to be used at the secondary level. To do so, an “Understanding by Design” approach was used along with educational theories of internal motivation to create lessons embedded in contexts that are of interest to high school students. In order to test whether these contextualized lessons are effective in leading to more interest in STEM and energy among students, a model for delivering the lessons to students in an informal environment is proposed along with student surveys and assessments.

The motivation for using more contextualized lessons is to create content that may be able to engage students more than current prevalent pedagogical techniques being used at the secondary level. While these prevalent techniques certainly have worked and continue to work well for some students, they certainly do not work well for all students. By exploring new methods of lesson delivery, techniques that help more diverse learners succeed could be discovered and implemented in classrooms across the nation.

2 Background

In 2019, a sample of 1,039 Americans was asked a series of questions about climate change. One-third of these Americans believed that global warming is not caused by human activities (Saad, 2019). In 2016, more than 90% of publishing climate scientists believed that global warming is caused by human activities (Cook, 2016). In that same year, a survey of 1500 public science teachers showed that less than a third of the middle school teachers surveyed and less than half of the high school teachers survey were aware that more than 80% of climate scientists believed that global warming is caused by human activities (Plutzer, 2016). These figures show that there is a huge inconsistency between the beliefs of average Americans, scientific researchers, and public-school teachers on human activity and the environment (*Figure 1*).

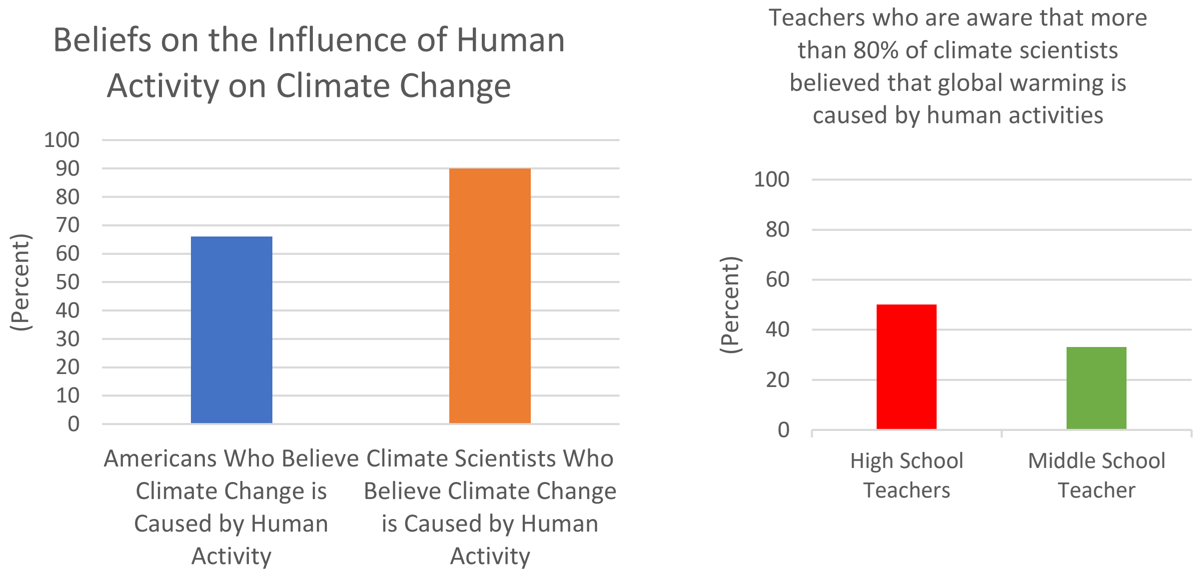


Figure 1. Citizens' and publishing climate scientists' beliefs on the effects of human activity on climate change and public-school teachers awareness of publishing climate scientists' beliefs.

Miscommunication between research scientists and citizens can be harmful to communities and to economies. Citizens who are misinformed or uninformed about energy cannot be expected to use and conserve energy responsibly, nor can they be expected to thoughtfully vote on energy related policies. While the misuse of energy and poor decisions regarding its generation and use are certainly harmful to the environment, they are also detrimental for those who are misinformed. One study comparing families with similar gross incomes showed that households that spend more than 10% of their income on energy bills were twice as likely to remain in poverty two years later (Bohr & Mccreery, 2019).

Industry is also being directly affected by insufficient education on energy, as many industry leaders are stating that there have not been enough people to fill positions in the energy sector in the past decade (Chen, Tomsovic & Aydeniz, 2014). Simultaneously, several groups are being underrepresented in many energy sectors. In 2019, Women made up just 26% of the solar workforce in the US – even though they compose 47% of the US workforce. Similarly, African Americans make up less than 8% of the solar workforce despite representing 12% of the US workforce (Solar Industry Diversity Study, 2019). The future of the energy industry may feel the results of this miscommunication as well. For instance, only 12% of undergraduate engineering degrees are in electrical engineering, and only 11.5% of these degrees were earned by women (ibid). This suggests that high quality educational opportunities in energy-related topics are sparse for many people, and even more so for members of underrepresented groups.

This underrepresentation of minorities in energy industries may be related to access to high quality science, technology, engineering, and math instruction. Racial minorities, for example, are disproportionally represented in low socioeconomic groups – partially due to discrimination and systematic racism (Budge, Thai, Tebbe, & Howard, 2016). People with lower socioeconomic statuses have been consistently shown to have less access to education and training in STEM fields (STEM 2026, 2016; Xie, Fang, & Shauman, 2015). For physics in particular, it has been shown that as socioeconomic status decreases, a smaller proportion of students are enrolled in higher-level physics classes (White, 2015). The same study shows that a smaller percentage of the African American and Hispanic student populations enroll in any physics courses than White and Asian student populations (ibid).The National Center for Educational Statistics reports that for the 2016-2017 school year, the national graduation rate for black and Hispanic students was about 10% less than the graduation rate for white students, while the graduation rate for American Indian and Native Alaskan students was nearly 20% less than that of white students.

Worcester Polytechnic Institute has developed a Research Experience for Undergraduates (REU) to address the underrepresentation of students from traditionally disadvantaged groups in clean energy fields. WPI's REU site, "Developing a Clean Energy Future with Underserved Students", focuses on introducing students from underrepresented groups to science and technology related to clean and renewable energies such as biomass, solar, and photonic devices. The REU students also participate in professional development seminars and community outreach opportunities. In culmination of their experience, the REU students delivered short lessons to a group of students from Girls, In. Worcester. Girls, Inc. is a non-profit organization that works to support the development of young women across the United States.

In August 2019, Worcester Polytechnic Institute's Department of Physics hosted thirty eighth-grade students from Worcester's Girls, Inc. program for a four-day long session pertaining to optics and clean energy. During the last day of the four-day long session, these students interacted with the REU students from the clean energy site at WPI. During these interactions, the REU students led the middle-schoolers through activities involving raspberry powered solar cells and solar spinners – devices that convert solar energy into mechanical energy (*Figure 2*).

Figure 2. REU student Tyler Burgess (University of Florida) helping Girls, Inc students put together solar spinners

Some REU students studying chemical engineering demonstrated catalysis to the entire group of middle-schoolers who were amused with the accompanying sounds of combustion. Other REU demonstrations involved changing the incident angle and wavelength of light shining on solar panels and altering a wind turbine's blade shape to change its efficiency (*Figure 3*). On the same day, students presented their own findings from visits to some of WPI's research labs (*Figure 4*).

Figure 3. REU student demonstrating the effect of incident angle and wavelength of light on power output of solar panels.

Figure 4. Students from Girls, Inc. Eureka! Program presenting their experiences from the summer session to professors, graduate and undergraduate students, and other middle-school students.

The students were given a survey about their feelings about clean energy before the start and after the conclusion of the session. The survey included the following statements:

1. I am interested in studying science, technology, engineering, and math (STEM).
2. I am interested in clean energy.
3. Learning something new in my STEM classes or elsewhere is applicable to my daily life.
4. Learning something new in my STEM classes or elsewhere enables problem-solving to real-life applications.

The students were asked whether they strongly agree, agree, disagree, or strongly disagree with the four statements. Results of the surveys were then analyzed using a paired-t test. Results from the pre-survey (*M* = 1.59, *SD* = 0.50) and the post survey (*M* = 1.76, *SD* = 0.58) suggested that the students were less interested in studying science, technology, engineering, and math after the summer session, *t*(29) = 2.42, *p* =.01. However, the paired-t tests failed to reject the null hypotheses for statements 2, 3, and 4, suggesting that the summer session did not make the students more interested in clean energy nor believe that learning something new in their STEM classes or elsewhere could apply to their daily lives or enable them to solve problems with real-life applications.

It is not clear as to why some students were less interested in studying science, technology, engineering, and math after the summer session. However, the open-ended responses may provide some clues. When asked how we could improve their learning experience, 50% of students suggested that more time should be spent completing hands on activities less time should be spent on lectures. 15% of the students wanted more engaging presentations and explicitly stated that they did not like slide show presentations. Another 15% of students suggested that the program leaders and assistants use simpler language and explain complex terminology when it comes up. Other suggestions included making the summer session more organized and feel less like school. One student wanted the program leaders and assistants to improve their social skills.

These results informed the design of lessons for this project. Most importantly, the lessons are designed to be student-centered, giving less time for lectures and more time for student learning activities. This was done in part by including Interactive Lecture Demonstrations, which allow an instructor to give important information while also allowing students to more actively participate in the lecture. Additionally, most vocabulary terms are introduced in group discussion. This allows for terms to be defined in the words of several students, hopefully helping bridge the language barrier between instructors and students.

The actual implementation of these lessons is likely to be first carried out in an informal learning environment, such as a summer session at WPI. While the lessons delivered to students in an informal setting are very similar to those delivered to students in a formal setting, there are a few practices that are particularly effective in informal environments. It has been suggested that students in informal STEM learning environments respond very well to activities that apply math and science skills and result in a feeling of accomplishment (Denson et al., 2014). Students also appreciate learning activities that expose them to new opportunities, such as exploring research laboratories or visiting project sites (ibid.). It has also been shown that interacting with STEM professionals such as researchers and professors lead to increased effort among students (Schnittka et al., 2011). These considerations helped guide the design of an informal learning experience based on the formal lessons designed for this project.

3 Methodology

Understanding by Design

All of the lessons created to teach students about energy for this project were designed using a type of backwards design called Understanding by Design (Wiggins & Mctighe, 2013). Backwards design is a style of curriculum design where the learning activities that students will take part in are the last elements of a lesson to be considered. Using Understanding by Design, the first aspect of a lesson to be considered is what the students should understand by the end of the lesson. Then, the teacher may decide how to assess student understanding before finally choosing the learning activities through which the students will gain this understanding.

Setting Desired Results

By first setting desired results for student understanding, the Understanding by Design method avoids creating lessons that are too focused on learning activities or curriculum coverage (Wiggins & Mctighe, 2013). Lessons focused on learning activities may occupy students time, but it is very likely that these lessons will not ultimately lead to improved understanding among students. Focusing mostly on curriculum coverage, it may be unlikely that students will actually engage with the material. Though they may memorize facts in class, this is not ideal for giving students knowledge that they can use to improve the world or compete in industry.

Using Understanding by Design, the teacher starts by thinking about what students should understand about a topic. This is especially useful in teaching physics at the secondary level, where students can often be bogged down by equations and mathematics only to leave the class without gaining a deeper understanding of how the world they are expected to contribute to works. With getting students to understand the physical world as their main goal, a physics teacher may now carefully design lessons that will be more likely to help students learn.

The understandings set in this project are informed by the Next Generation Science Standards, a framework used in schools across the United States of America (Next Generation Science Standards, 2019). The Next Generation Science Standards encourage science teachers to design student-centered lessons – lessons that focus on hands-on activities, student collaboration, and first-hand experience. The complete set of standards used to design the lessons for this project are in Relevant Next Generation Science Standards.

In each lesson, student learning is guided by an essential question. Essential questions make students think about the ideas that are central to a topic. These questions cannot typically be answered in a single sentence, and so encourage students to ask more questions and explore foundational ideas that support a topic. Drafting essential questions can be very challenging, especially in a field as fundamental as physics. As a physics teacher, one must ask themselves what ideas are central to a physical concept and what ideas can be put on the back burner. Deciphering between which ideas are essential and which ideas are complementary requires a strong knowledge of the applications of the subject matter.

After objectives for student understanding are set, more measurable objectives must be put in place. While a student's understanding of why a block sliding down a ramp has an increasing velocity cannot be easily measured, that student's ability to solve a problem using the Law of Conservation of Energy can. For this reason, content objectives are listed in each lesson plan in order to guide teachers in their assessment of student understanding.

In addition to setting objectives for content knowledge, a teacher should also set objectives for students' use of technical language and vocabulary. Language objectives and necessary vocabulary should be stated both for students who are English Language Learners and for those who are native English speakers.

Assessment

Data driven teaching allows for teachers to know what their students have learned and to make any necessary adjustments to their lesson deliver. For this reason, each lesson in this project includes an opportunity for assessment. Each assessment is analyzed with clear and measurable criteria. Including assessment in each lesson does not mean hat students are quizzed or formally tested each class. There are many ways to determine whether a student has learned in a fair and measurable manner. The lessons designed for this project include formal, informal, formative, and summative assessments.

Assessments may be formal or informal. Formal assessments, like tests and quizzes, use standardized measures to grade students with a number or percentage. Other assessments are informal, like projects or presentations. These assessments still assess a student's understanding of a topic but are graded in a more subjective manner than formal assessments.

Assessments may also be either formative or summative. Formative assessments tend to be low-stakes assessments that are given before and during lesson delivery to help the teacher make necessary adjustments to their practice, while summative assessments tend to be higher-stakes assessments given at the end of a lesson or unit to determine how well a student understands material (Dixon & Worrell, 2016). Examples of formative assessments include homework, observations, and self-evaluations while examples of summative assessments include projects, exams, and presentations.

Designing a Learning Plan

The last step of creating a lesson using Understanding by Design is to design a learning plan. Each lesson in this project includes introduction activities, learning activities, and closing activities. The learning plan in each lesson for this project is often written using statements like "The teacher will…" so that these lessons may be used by a wide range of educational professionals. The teacher also focuses on providing students with lessons catered towards multiple types of intelligences, applications, student groupings, and delivery methods.

Introduction activities, sometimes called warm-up activities, should get students motivated for and engaged in the lesson. Many of the introduction activities used in this project take the form of Interactive Lecture Demonstrations (ILDs) (Mazzolini & Edwards, 2012). To carry out an Interactive Lecture Demonstration, an educator will ask students to make predictions about a physical scenario, then ask the class to share their predictions to get a sense of what students think will happen. After the educator performs the experiment, they ask students to discuss why the observed outcome occurred. Interactive Lecture Demonstrations are especially valuable tools for teaching physics because they challenge students' beliefs of the natural world, often making them want to learn more. Interactive Learning Demonstrations can often lead to greater understanding of physical concepts than lectures alone, especially in areas that are more difficult for students like electricity and magnetism (Mazzolini, Daniel, & Edwards, 2012).

Following the warm-up activities are the main learning activities. In this unit, the main learning activities tend to be student centered rather than teacher centered. Due to the nature of concepts in physics taught at the secondary level, these learning activities will vary greatly. Some may look more traditional, such as written exercises and worksheets, while others take approaches more prevalent in the modern classroom, like group exercises and on-line research.

After the main learning activities, some sort of closing activity is delivered by the teacher. The purpose of the closing activity is to give students a sense of closure. Many closing activities summarize what was learned in the lesson or recap the main ideas. Sometimes, closing activities leave students with a new perspective or idea to think about after they leave the class.

At the end of each lesson plan, the educator makes note of multiple intelligences addressed, student grouping, and delivery methods used in the lesson. Multiple Intelligences Theory, largely developed by Harvard University psychologist Howard Gardner, appreciates one's ability to solve problems and demonstrate intelligence in a contextualized and naturalistic setting

(Armstrong, 2009). Indeed, Gardner's emphasis on creating contextualized classroom settings has influenced the goal of this project, which is to teach energy concepts to students in a more engaging way. Similar to the idea of multiple intelligences, a great deal of work has shown that different students respond differently to various types of student groupings and lesson delivery methods. A teacher, and especially one of physics, should always try to address various intelligences and learning styles throughout the course of a unit.

Contextualization

Although there has been a huge increase in awareness of the importance of STEM education recently, it is still hard to answer the student question, "when will I ever need to know this?". This is a great question for any educator to consider. It is especially true at the high school level that students need to be engaged before they can learn. More so for physics, a traditional lecture style approach is not very conducive to engaging students at the secondary level. Predominantly lecture-style secondary physics classes have been shown to be lead to less significant student achievement and success on formal summative assessment than styles such as inquiry-based instruction or flipped classrooms (Şen, 2010; Zownorega, 2013) Even at the undergraduate level it has been shown that classes involving active learning activities rather than lectures have a lower failure rate and higher exam scores among students (Freeman et al., 2014).

In order to increase student understanding and knowledge retention, the lessons in this unit were designed with the hope to increase student engagement. Increased student engagement has been shown to improve students' motivation, participation, and achievement (Sawyer, 2006). It has also been suggested that putting concepts in contexts with which students are familiar is strongly correlated with increased student engagement with the concepts (Krause et al., 2016). For this reason, the lessons in this project were developed with contextualization as a main element. Contextualized lessons deliver information to students using familiar real-world experiences to help connect new information to prior knowledge. Lessons in this project, for example, use real-world contexts such as climate change, nutrition, and urban design. In fact, there are many educators that believe students must connect new knowledge to old knowledge in order for learning to happen. Contextualization has also been shown to be helpful for catering to students of various learning styles (Chen, Tomsovic & Aydeniz, 2014).

Physics lends itself well to contextualization for several reasons. Since every experienceable phenomena can be related back to physics, it isn't too hard to give context to problems, projects, and other work. Additionally, many concepts in physics taught at the secondary level build upon one another. For instance, by the time the lessons in this energy unit are delivered, a class will likely already have covered one and two-dimensional kinematics as well as Newton’s Laws of Motion – both of which can support the attainment of knowledge in energy related fields of physics. One technique through which old information can help the acquisition of new information is called *bridging* (Ambrose & Myer, 2010). Bridging is used in this unit when electrical potential energy is introduced. Students have already learned about gravitational potential energy when they are introduced to electrical potential energy, so relating a change in potential over a circuit element to a change in height on a hill can help students understand electrical potential. It is important, however, that the limitations to any analogy are clearly stated.

Perhaps one of the greatest benefits of designing contextualized lessons is to show students a topic’s instrumental value. Students see instrumental value in a lesson when they can directly relate their learning experience to betterment in their future, such as getting a good job, helping the environment, or improving their quality of life (Ambrose & Myer, 2010). In this unit, instrumental value is shown to students by introducing them to possible careers related to physics and energy, benefits of having energy-related knowledge for communities and families, and real problems that can be solved using logic and reason. Renewable energy science and climate change provide great context for physics students in the modern classroom, as these topics are relevant and of interest to many students. In one survey from the United Nations Environment Program, 73% of young people said they currently feel the effects of climate change and 84% of the young people agreed that they need more information to prevent climate change (Youth Stats, 2011). This modern problem provides excellent context for the discussion of physics topics like energy and climate science, and being able to design lessons within this context could help motivate students to learn more about these topics and perhaps continue into a career related to these topics. The four lessons in this unit are designed to introduce students to the concept of energy, its conservation, its relation to life sciences, and how society generates, stores, and uses it.

4 Lesson Design

The energy curriculum designed in this project consists of one unit, which is composed of five lessons. A unit plan provides an overview of the lessons, including a summary of the lessons, objectives, and assessment evidence. The following lessons provide a set of instructions designed to be followed by any educator in order to deliver a contextualized, student-driven learning experience to students. Finally, adaptations and modifications for the delivery of these lessons in informal learning environments are proposed.

4.1 Formal Lesson Plans

Unit Plan

Subject: **Physics**	
Unit: Energy In this unit, students will learn about how to qualitatively and quantitatively describe energy. Students will first learn about what energy is on the micro and macro scales. Then, students will investigate how energy is transformed, stored, and used for a wide range of applications in the physical and life sciences. Finally, students will apply their knowledge about energy to both design a device that can transform one type of energy into another and orally communicate scientific ideas about energy.	
DESIRED RESULTS	
Students will be able to: • Use models to relate energy the energy of a system to the energy of the elements in that system. • Calculate the kinetic, potential, and thermal energies of a system. • Identify energy demands in various societies and determine the optimal energy sources for those societies. • Communicate ideas about the transformation, storage, and use of energy and their environmental impacts to a wide range of demographics. • Evaluate the validity of social and political claims about energy. • Explain how organisms use energy to carry out all life functions.	
ESSENTIAL QUESTIONS	**KNOWLEDGE AND SKILL**
• How and why can energy be represented quantitatively? • How can the energy needs of a society be met in order to promote the welfare of its people and the environment? • Can technology efficiently capture energy being transmitted by waves? • Is it important for the members of a society to understand how they use energy and where their energy comes from? • How do organisms attain and use energy to carry out life processes?	• Calculate the kinetic, potential, and thermal energies of a system. • Use the Law of Conservation of Energy to predict the behavior of a system. • Use the mathematical relationship between the wavelength, frequency, and speed of a wave to describe its energy. • Research a topic and organize gathered information in order to effectively communicate findings. • Judge the validity of a claim using factual evidence.
ASSESSMENT EVIDENCE	
• Designing and creating a device that can transfer one form of energy into another form of energy. • Present information about the role of energy in society orally and in writing. • Calculate the energy of systems and waves in a project format.	

Lesson 1: Introduction to Energy

Lesson Plan Title: Introduction to Energy

Subject/Course: Physics

Unit: Energy

Grade Level: Junior/Senior

Overview of and Motivation for Lesson:

In this lesson, students will be introduced to the concept of energy. First, they will share their preconceived ideas about energy and its importance in society. Then, they will be introduced to the idea that a system is limited by its energy. Finally, students will explore some of the common forms of energy and their related formulae.

Stage 1-Desired Results

Standard(s):

Next Gen

HS-PS3-2.

Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).

Aim/Essential Question:

What is energy and how can it be described?

Understanding(s):

Students will understand that . . .

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system.
- The amount of energy in a system limits the behavior of that system
- Energy can be manifested in various forms, such as kinetic, thermal, or potential energy.

Content Objectives:	Key Vocabulary
Students will be able to . . . • Identify different forms of energy • Recognize relationships between variables in energy formulae	• Energy • Kinetic, Thermal, Chemical, and Potential Energy

Stage 2-Assessment Evidence

Performance Task or Key Evidence

- Energy Formulae Mini-Posters

Key Criteria to measure Performance Task or Key Evidence

- Proper Identification of Energy Formulae and variables related to energy

Stage 3- Learning Plan

Learning Activities:

Warm-Up: What is Energy?

The teacher will ask students to write down their answers to the following questions in complete sentences:

1. What do you think Energy is?
2. In what contexts have you heard the word "energy" be used?
3. What types of energy-related jobs or careers exist?

The teacher should give students 2 minutes to write down their answers to these questions independently, then give 2 minutes for students to discuss their thoughts with those around them. Then, the teacher should lead the class through a discussion of some of the common answers. One worthwhile discussion would pertain to how energy-related jobs have changed in the past and how they may change going into the future.

The teacher should collect these answers to get a sense of student understanding about energy.

Learning Activity 1: Thunderstorm Orchestra

The teacher will designate three sections of students. The teacher will then orchestrate these three groups to mimic the sounds of a thunderstorm. To do this, the teacher will follow these steps:

1. Instruct the first group to start lightly rubbing their hands together
2. Instruct the second group to start lightly snapping (if students can't snap, they can clap with two fingers)
3. Instruct the first to groups to start making their respective noises louder as the third group starts to gently pat their thighs
4. Explain that when the teacher points to the first group, they will clap once. The third group should clap once as fast as they can after they hear the first group clap
5. After a few moments, the teacher will instruct each group to make their respective noises softer and softer until the third group is instructed to stop, followed by the second group, then finally the third group

After this thunderstorm is orchestrated, the teacher will ask students to take one minute to list as many forms of energy present in a thunderstorm as they can (i.e. light energy as lightning, sound energy as thunder and rain drops hitting the ground/roof, kinetic energy of falling raindrops, potential energy of rain drops high in the sky). After one minute, the teacher will ask students to share the types of energies they identified.

Learning Activity 2: Energy Poster Design

The teacher will place students into groups and assign each group a form of energy. Based on the level of the course and the number of students in each class, the teacher could assign the following types of energies to the groups:

- Kinetic Energy
- Gravitational Potential Energy
- Elastic Potential Energy
- Electric Potential Energy
- Thermal/Internal Energy
- Photon Energy

For larger class sizes, the teacher may choose to assign multiple groups the same form of energy.

The teacher will then instruct each group to research their assigned type of energy to find the following:

a) A definition of this type of energy
b) An equation for this type of energy
c) Definitions for each variable in the equation
d) Examples of things that have/emit this type of energy

The teacher will then give students Chromebooks or textbooks, blank posters and drawing materials to complete their posters.

Summary/Closing: Poster Presentations

Each group will present their posters to the class to describe their findings. If time permits, the teacher should encourage students to ask clarifying questions to the presenting group.

The teacher should emphasize that since each form of energy has a correlated equation, energy must be able to be described quantitatively. The teacher may then note that the reason this is the case will be discussed further in the unit.

Multiple Intelligences Addressed:

☒ Linguistic
☒ Spatial
☐ Logical-Mathematical
☒ Interpersonal
☒ Musical
☐Intrapersonal
☐ Bodily-kinesthetic
☒Naturalistic

Student Grouping

☒ Whole Class ☒ Small Group ☒ Pairs ☒ Individual

Instructional Delivery Methods

☐ Teacher Modeling/Demonstration
☐ Cooperative Learning
☒ Independent Projects
☐ Lecture
☐ Centers
☒ Discussion
☐ Problem Solving

Homework/Extension Activities:

Calculating Energy

Materials and Equipment Needed:

- Poster Board and Drawing Supplies
- Chromebooks, smartphones, or textbooks

Lesson 2: Conservation of Energy

Lesson Plan Title: Conservation of Energy

Subject/Course: Physics

Unit: Energy

Grade Level: Junior/Senior

Overview of and Motivation for Lesson:

In this lesson, students will investigate a system in which gravitational potential energy is transferred into kinetic energy using the Law of Conservation of Energy.

Stage 1-Desired Results

Standard(s):

Next Gen

HS-PS3-1

> Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

Aim/Essential Question:

> Why can energy be described as a number?

Understanding(s):

Students will understand that . . .

- Energy can be described with a single number because the total energy in a closed system is conserved.
- **Energy can change forms: for instance an object could lose potential energy to gain kinetic energy.**

Content Objectives:	Key Vocabulary
Students will be able to . . . • **Write an equation relating the initial and final mechanical energies of a system** • Collect data to support the Law of Conservation of Energy	• Mechanical Energy • Kinetic and Potential Energy • Conservation of Energy

Stage 2-Assessment Evidence

Performance Task or Key Evidence

- Energy Conservation Lab

Key Criteria to measure Performance Task or Key Evidence

- Students will be able to write a formal lab report to communicate their results from the Energy Conservation Lab following the attached rubric

Stage 3- Learning Plan

Learning Activities:

Warm-Up: ILD: Pendulum Drop

The teacher will set up a pendulum such that it can be dropped from rest touching a domino or other unsteady object (If possible, the teacher may instead set up a larger pendulum attached to the ceiling and have it touch their chin before dropping it). The teacher will then ask students to predict whether the pendulum will knock over the domino when it swings back. Students will have one minute to write down their predictions, then another half of a minute to discuss their predictions with those around them. After the pendulum is dropped, the teacher will ask the students why the pendulum did not knock over the domino. The teacher will finally explain that the energy of a closed system will remain constant due to the Law of Conservation of Energy.

<u>Learning Activity 1: Conservation of Energy Lab</u>

Students will work in pairs to complete this Conservation of Energy Lab. Based on the proficiency level of the class, the teacher may have students write a full formal lab report or use a template.

<u>Summary/Closing: Lab Results Discussion</u>

The teacher will lead the class through a discussion of lab results with the following questions:

- How was the initial energy of the system related to the final energy of the system?
- Do we think the initial and final energies of the systems being similar is a coincidence?
- What may have caused the initial and final energies of the system to be slightly different?

Multiple Intelligences Addressed:

☒ Linguistic
☒ Logical-Mathematical
☐ Musical
☐ Bodily-kinesthetic
☒ Spatial
☒ Interpersonal
☐ Intrapersonal
☐ Naturalistic

Student Grouping

☐ Whole Class ☒ Small Group ☒ Pairs ☐ Individual

Instructional Delivery Methods

☐ Teacher Modeling/Demonstration	☐ Lecture	☒ Discussion
☒ Cooperative Learning	☐ Centers	☐ Problem Solving
☒ Independent Projects		

Homework/Extension Activities:

Watch this video on Work, Energy, and Power and take notes for next lesson

Materials and Equipment Needed:

- Low Friction Track & Carts
- Motion Sensor/Photogate/Timer

Lesson 3: Energy and Life

Lesson Plan Title: Energy and Life

Subject/Course: Physics

Unit: Energy

Grade Level: Junior/Senior

Overview of and Motivation for Lesson:

In this lesson, students will explore the relation between physical concepts of energy and life sciences, mainly in that all basic life functions require energy.

Stage 1-Desired Results

Standard(s):

Next Gen

HS-LS1-7.
Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.

HS-LS2-4.
Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.

Aim/Essential Question:

- How do organisms obtain and use energy to carry out life processes?

Understanding(s):

Students will understand that . . .

- Organisms need energy to carry out all basic life functions
- Organisms get usable chemical energy from food or from the sun

Content Objectives:

Students will be able to . . .

- Recognize energy transfers in a system
- Use the Law of Conservation of Energy to determine the energy needed for an organism to carry out a task

Key Vocabulary

- Calorie, kilocalorie
- Autotroph/Heterotroph
- Chemical Potential Energy
- Work
- Power

Stage 2-Assessment Evidence

Performance Task or Key Evidence

- Tracing the Steps Activity

Key Criteria to measure Performance Task or Key Evidence

- Students will be able to identify energy transfers in a system and calculate the amount of energy needed for a task.

Stage 3- Learning Plan

Learning Activities:

Warm-Up: ILD: Burning Calories

The teacher will lead students through an interactive learning demonstration. The teacher will explain that a low-calorie snack and a high-calorie snack, each with the same mass, will be burned under a tube of water. The students will write down what they think will cause a greater temperature change in the water and why. When students are done writing down their predictions, they will share them with the class. Then, the teacher will light each snack on fire using a Bunsen burner then hold it under a tube of water to determine the temperature change in each tube of water. After each snack is extinguished, the teacher will ask one or two students to read each thermometer and write the change in temperature on the board. The class will then discuss why they think they saw the results they did.

Learning Activity 1: TED Ed – What is a calorie?

Students will watch this TED Ed video and write down three questions and/or ideas that stuck out to them the most as they watched it.

Learning Activity 2: Tracking Steps

Students form groups to complete the Tracking Steps assignment. In this assignment, students will learn about Work and Power as they calculate the energy it takes to climb a flight of stairs.

Learning Activity 3: Biofuel Research Projects

Students will begin by watching this video on modern biofuels. Then, they will choose a biofuel to research and follow the **Biofuel Research Project** assignment to learn more about their chosen biofuel.

Summary/Closing: Project Presentations

Students will present their Biofuel Research Projects.

Multiple Intelligences Addressed:

☐ Linguistic ☒ Logical-Mathematical ☐ Musical ☐ Bodily-kinesthetic

☐ Spatial ☒ Interpersonal ☐Intrapersonal ☒Naturalistic

Student Grouping

☐ Whole Class ☒ Small Group ☒ Pairs ☐ Individual

Instructional Delivery Methods

☒ Teacher Modeling/Demonstration ☐ Lecture ☒ Discussion

☐ Cooperative Learning ☐ Centers ☐ Problem Solving

☒ Independent Projects

Homework/Extension Activities:

- Watch this video about designer Theo Jansen's creations. These designs emphasize the energy and energy transfers required to carry out basic functions.

- Complete the Work and Power Extension Problems

Materials and Equipment Needed:

- Safety Glasses & Lab Coat
- Bunsen Burner
- Dry High-Calorie Snack (Potato chip, Corn Chip)
- Dry Low-Calorie Snack (Veggie Chips, Dried seaweed)
- Scale

Lesson 4: Energy from Clean and Renewable Sources

Lesson Plan Title: Energy from Clean and Renewable Sources

Subject/Course: Physics

Unit: Energy

Grade Level: Junior/Senior

Overview of and Motivation for Lesson:

In this lesson, students will explore how energy from different clean and renewable sources is captured and stored. Then, they will design a device that can convert one form of energy to another.

Stage 1-Desired Results

Standard(s):

Next Gen

HS-PS3-3.
Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
HS-PS4-1.
Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

Aim/Essential Question:

How can energy from clean and renewable sources be effectively captured, stored, and used?

Understanding(s):

Students will understand that . . .

- Clean energy sources do not cause pollution when they are used
- Renewable energy is harnessed from natural sources like wind, sunlight, ocean waves, and geothermal energy.
- The energy carried by a wave is related to its wavelength, frequency, and speed.

Content Objectives:	Key Vocabulary
Students will be able to . . . • Differentiate between clean and renewable energy sources • Determine factors that change the efficiency of a device	• Angle of Incidence • Wavelength • Frequency

Stage 2-Assessment Evidence

Performance Task or Key Evidence

- Clean and Renewable Energy Centers

Key Criteria to measure Performance Task or Key Evidence

- Students will be able to answer questions related to clean and renewable energy sources in complete sentences.

Stage 3- Learning Plan

Learning Activities:

Warm-Up: ILD: Measuring the Speed of Light

For this Interactive Lecture Demonstration, the teacher will ask students to write down their predictions for what will happen when the turn table on a microwave is removed and a piece of food is heated in the microwave. Students will then have time to write down their predictions as to what will happen to the food, then to share their thoughts with other classmates. After the teacher gets some students to share their predictions, the teacher will take the turntable out of the microwave and put the food in, heating it at 5-10 second time intervals until the food is burnt on spots at even intervals (antinodes). The students will then write down what they observed and reflect upon their predictions accordingly. The teacher may then lead the class through a discussion based on the following questions:

- Why do you think the burnt spots are evenly spaced out?
- What forms of energy were present inside the microwave when it was turned on?
- How did the energy get to the food?

Depending on the proficiency level of the class, the teacher may decide to have students measure the distance between the burnt spots on the food to determine the wavelength of the electromagnetic radiation created inside of the microwave. If the average distance between the burnt spots on the food is d, then students may experimentally find the speed of light by using the following formula:

$$v = \lambda f$$

Or in this case:

$$c = 2df$$

Where f is the frequency of the electromagnetic waves. A range of frequencies emitted by the microwave will likely be listed on the side of the microwave.

Learning Activity 1: Defining Clean and Renewable Energy Sources

The teacher will ask the class to define the following terms: “Clean Energy” and “Renewable Energy”. Students may offer context, connotations, or examples as the teacher guides the class towards arriving at the following definitions:

Clean Energy – energy derived from sources that do not cause pollution when used.

Renewable Energy – energy derived from naturally restoring sources.

Then, the teacher will list examples of energy sources and the students will have to determine whether the sources are clean, renewable, both, or neither. Students may show their answers with two different colors of construction paper by holding up one color for clean sources, another color for renewable sources, both colors for clean and renewable sources, and neither paper for sources that are not clean nor renewable.

Here are some examples of sources that could be discussed

- Wind Energy - Clean & Renewable
- Coal - Neither
- Biofuels - Renewable
- Natural Gas - Neither
- Solar - Clean & Renewable
- Geothermal - Clean & Renewable
- Hydropower - Clean & Renewable
- Nuclear - Clean

Learning Activity 2: Clean and Renewable Energy Learning Centers

Students will work in small groups to visit and complete tasks at Clean & Renewable Energy Learning Centers – Solar: one focused on solar energy, one focused on wind energy, and one focused on chemical energy. See the accompanying documents for instructions to be posted at each station.

Before starting the activities, the teacher will ask students to define "Clean Energy" and "Renewable Energy"

After completing the activity and questions at each center, students will be given 1 minute to answer the following questions:

1. Describe the energy transfer occurring in this device. What type of energy is put into the system and what type of energy is put out?
2. Is this device a source of clean energy, renewable energy, or both?

See the accompanying documents for instructions to be posted at each station.

Learning Activity 3: Sustainable Home Design

Students will complete the Sustainable Home Design activity, using both active energy systems and passive design elements. The students will then build a model of their sustainable homes and explain how each system or element works to produce or conserve energy.

Summary/Closing: Sustainable Home Presentation

Student Groups will present their projects to the class.

Multiple Intelligences Addressed:

☒ Linguistic
☒ Logical-Mathematical
☐ Musical
☐ Bodily-kinesthetic
☐ Spatial
☒ Interpersonal
☐ Intrapersonal
☒ Naturalistic

Student Grouping

☐ Whole Class
☒ Small Group
☒ Pairs
☐ Individual

Instructional Delivery Methods

☐ Teacher Modeling/Demonstration
☐ Lecture
☒ Discussion
☒ Cooperative Learning
☒ Centers
☐ Problem Solving
☒ Independent Projects

Homework/Extension Activities:

Watch at least one of the following videos and write a paragraph describing the ways in which the house or city generates or conserves energy:

Future Homes: Self-sufficient living in off-the-grid Tasmanian home

Off-Grid Cabin with Energy Wheel, Floating Bed & Indoor Climbing Wall

Sustainable City | Fully Charged

Materials and Equipment Needed:

Candle Soot Activity

- Candles & Grill Lighter
- Pan
- Brush

Solar Center

- Voltmeters
- Photovoltaic Cell
- UV & Multicolor lamp
- Protractor

Wind Center

- Wind-Mill Base
- Fan
- Construction Paper

DC Motor

- D Battery
- Rubber Bands/Tape
- Paperclips
- Small Magnets
- Wire with one frayed end (half of the coating is scraped off)

4.2 Informal Lesson Delivery

To be adapted for delivery in an informal setting, many of the same Interactive Lecture Demonstrations and Learning Activities may be used, though they should be adapted to fit the proficiency level of the students as well as the format of the learning session. Below is a list of activities and adaptions from the lessons that would be most conducive to an informal learning environment:

Lesson 1: Introduction to Energy

- Thunderstorm Orchestra
- Energy Poster Design

Lesson 2: Conservation of Energy

- ILD: Pendulum Drop
- Conservation of Energy Lab
    - This lab may be completed with a simpler template if necessary. Group results could also be used and analyzed together

Lesson 3: Life and Energy

- TED-Ed Video: Burning Calories
- Biofuel Research Project

Lesson 4: Energy from Clean and Renewable Sources

- Clean and Renewable Energy Centers
- Sustainable Home Design

In addition to these activities, students may strongly benefit from interacting with undergraduate students and researchers (Denson et al., 2014). Demonstrations from REU students completing research projects at the “Developing a Clean Energy Future with Underserved Students at WPI” site were one of the favorite activities of the students from Girls, Inc. during the 2019 summer session. Following a similar format as was carried out for the last summer session, students could cycle through different energy related REU presentations and complete an activity at each station. These REU presentations may be best delivered after the learning activities listed above to reinforce some ideas covered in the prior activities.

Lab visits would also provide excellent learning opportunities for students. There are many accompanying activities that could give students an active role rather than a passive one while visiting labs. For instance, students could research each lab before visiting in order to prepare 3-5 questions for the researchers. Additionally, students could take pictures in each lab and write about a day in the life of a research scientist. Similarly, students could report on the steps that a researcher took to arrive at their current position. Interacting with researchers could be both supplementary and complementary to the learning activities listed above.

5 Future Research

In order to test whether these lessons lead to increased student interest in STEM and energy-related topics as well as how to best develop new lessons, these learning activities should be delivered to a group of students. One group that these lessons could likely be delivered to is the Girls, Inc. Eureka! Program that was involved in the summer session from August 2019. The group will be a different cohort of students, but the students are of similar backgrounds and demographics.

A pre and post survey could be used to determine the efficacy of the lessons, using the Likert scale to determine whether strongly disagree, disagree, agree, or strongly agree with each of the following statements:

1. I am interested in studying science, technology, engineering, and math (STEM).
2. I am interested in learning more about energy.
3. I often make connections between what I learn in my science class and my daily life.
4. I think studying STEM topics could help me get a good career.
5. I think studying STEM topics could help me improve my community.

In addition to responding to the five statements above, students will answer the following questions after the delivery of the lessons:

1.) What energy related topics would you like to learn more about?

2.) What were your favorite activities from these lessons? Why were these activities your favorite?

3.) What were your least favorite activities from these lessons? What do you think could be improved about these lessons?

A paired-T test may again be used to analyze student responses to the pre and post surveys. After analyzing the results of the surveys, lessons may be revised by adjusting the difficulties or by changing activities within the lessons. By determining students' favorite activities, for example, the most engaging formats for learning activities may be determined. Similarly, determining the students' least favorite activities may help determine what could be improved about some of the lessons. By analyzing trends from students' responses to the three questions to be asked after the delivery of the lessons, new learning activities could be developed. These activities could either be extensions to the existing lessons, or they could form entirely new energy related lessons.

6 Appendix

Relevant Next Generation Science Standards

HS-PS3-1	**Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.** [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.]
HS-PS3-2.	**Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).** [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]
HS-PS3-3.	**Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*** [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.] [Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.]
HS-PS3-4.	**Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).** [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.]
HS-PS3-5.	**Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.** [Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [Assessment Boundary: Assessment is limited to systems containing two objects.]
HS-PS4-1.	**Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.** [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [*Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.*]
HS-PS4-3.	**Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.** [Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] [*Assessment Boundary: Assessment does not include using quantum theory.*]

HS-PS4-4.	**Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.** [Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.] [*Assessment Boundary: Assessment is limited to qualitative descriptions.*]
HS-PS4-5.	**Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*** [Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.] [*Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.*]
HS-LS1-7.	**Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.** [Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [*Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.*]
HS-LS2-4.	**Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.** [Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.] [*Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.*]

6.1 Accompanying Documents

Name ______________________________ Date ____________

Calculating Energy

$$K = \frac{1}{2}mv^2 \qquad U_g = mgh \qquad U_{spring} = \frac{1}{2}kx^2$$

Using the equation for an object's *Kinetic Energy*, solve each problem below.

1. Calculate the Kinetic Energy of a 70 kg person running at a speed of 6 m/s.

ANS: $K = \frac{1}{2}(70\ kg)\left(6\frac{m}{s}\right)^2 = 1{,}260\ J$

2. Find the mass of a truck driving on the highway at 26 m/s if the truck has a kinetic energy of 760,500 J.

ANS: $760{,}500J = \frac{1}{2}m\left(26\frac{m}{s}\right)^2 \rightarrow m = 2{,}250\ J$

3. How fast must a 0.15 kg arrow be shot in order to have a kinetic energy of 125 J?

ANS: $2J = \frac{1}{2}(0.15\ kg)v^2 \rightarrow v = 5.16\ m/s$

Now using the equation for an object's *Gravitational Potential Energy*, solve each problem below. Assume that potential energy is equal to 0J at ground level for each problem.

4. Calculate the Potential Energy of a 0.6 kg hawk flying at an altitude of 34 meters above the ground.

ANS: $U_g = (0.6\ kg)\left(9.8\frac{m}{s^2}\right)(34m) = 200\ J$

5. Find the mass of an airplane at an altitude of 10 kilometers if the airplane has a potential energy of 3.92 x 10^{10} J.

ANS: $3.9x10^{10}\ J = m(9.8\frac{m}{s^2})(10{,}000m) \rightarrow m = 400{,}000\ kg$

6. How far off of the ground must a 20 kg weight be lifted in order to have a potential energy of 350 J?

ANS: $350J = (20\ kg)\left(9.8\ \frac{m}{s^2}\right)h \rightarrow h = 1.79\ m$

Now using the equation for the *Potential Energy stored in a Spring*, solve each problem below. Assume that potential energy is equal to 0J at ground level for each problem.

7. Calculate the Potential Energy stored in a spring with a spring constant of 5 N/m that has been compressed 10 cm beyond its equilibrium point.

ANS: $U_{spring} = \frac{1}{2}(5\frac{N}{m})(0.1m)^2 = 0.025\,J$

8. Find the spring constant of a spring that has been stretched 0.5 m passed its equilibrium and has 12 J of stored energy.

ANS: $12\,J = \frac{1}{2}k(0.5m)^2 \rightarrow k = 96\,N/m$

9. How far must a spring with a spring constant of 10 N/m be compressed in order to store 100 J of energy?

ANS: $100J = \frac{1}{2}(10\,N/m)\,x^2 \rightarrow x = 4.47\,m$

Name________________________________ Partner's Name_________________________________

Conservation of Energy Lab

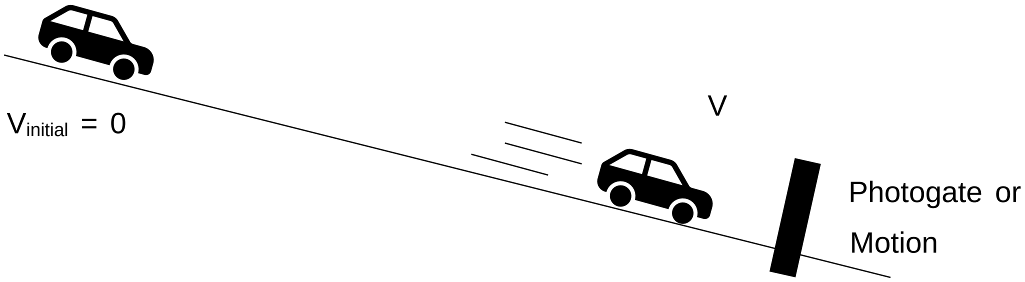
Context: A car is pulled over for speeding at the bottom of a hill. The driver claims that he was not purposely speeding, but that he had just picked up speed from going down the hill. If he started at rest at the top of the 10m high hill and an officer recorded his speed at the bottom of the hill to be 50 mph, how can it be determined whether the driver was speeding?

Introduction

In this lab, we will be measuring the initial and final energies of a system consisting of a cart on a ramp. We will then compare the initial and final energies of the system to find a pattern that can help determine whether the car in the problem above was speeding.

Procedure

To measure the initial and final energies of the cart on a ramp, use the following procedure:



1. Measure the mass of the cart that will be moving down the ramp. Record the mass of the cart below the table on the next page.
2. Prop the ramp up on an angle and attach the photogate/motion sensor to the bottom of the ramp.
3. Choose a spot at the top of the ramp from which the cart will be released and measure the height of this point on the track relative to the height of the track at the photogate/sensor (this will be considered a height of zero meters). Record the height in the table on the next page.
4. Drop the cart from the top of the ramp at least five times, recording the speed of the cart measured by the photogate/sensor in the table below. Be careful not to give the cart any initial speed while dropping it.
5. Change the slope of the ramp and repeat steps 2-4 to complete the data table.

Initial Cart Height (meters)	Final Velocity (m/s)					
	Trial 1	*Trial 2*	*Trial 3*	*Trial 4*	*Trial 5*	**Average**

Mass of Cart (kg): _______________

Analysis

Now we will calculate the initial and final energy of the cart for each of the three set-ups.

What type(s) of energy does the cart have at the top of the ramp?

What type(s) of energy does the cart have at the bottom of the ramp?

Calculate the initial energy of the cart for the three set ups below:

Initial Cart Height: ___________

Initial Energy: _____________

- -

Initial Cart Height: ___________

Initial Energy: _____________

- -

Initial Cart Height: ___________

Initial Energy: _____________

Calculate the final energy of the cart for the three set ups below using the **average velocities** from your data table:

Set-up 1

Final Energy: ____________

- -

Set-up 2

Final Energy: ____________

- -

Set-up 3

Final Energy: ____________

Now, calculate the **Change in Energy** ($E_{final} – E_{initial}$) for each set-up

Set-up 1:

Set-up 2:

Set-up 3:

Results & Conclusion

Answer the following questions:

In which set-up did the cart have the greatest initial energy?

In which set-up did the cart have the greatest final energy?

How does the initial energy of each system relate to the final energy of that system? Use your results from calculating the change in energy for each set-up to defend your answer.

If a physical property cannot be created or destroyed, we say that that property is *conserved*. Do you think that energy is a conserved quantity?

How was energy lost as the cart moved down the ramp?

Context: Now that you have determined that energy is a conserved quantity, determine whether the car that was pulled over had been purposely speeding or whether they had just picked up speed going down the hill.

Options for Educators:

To make this assignment more difficult, students could write their own procedures, create their own data tables, and analyze the data by themselves.

If the concepts of work have been introduced, the educator may also ask students to find the average force of friction exerted on the cart by the track.

Name ________________________________ Partners' Name(s) ______________________________

Tracking Steps

All basic life functions require energy. The purpose of this activity is to determine where this energy comes from.

To begin, we will find out how much energy you must exert to climb a flight of stairs.

First, measure the height of the staircase by measuring the height of a single stair, then multiplying by the number of stairs you will be climbing.

Next, have your partner time how long it takes you to climb the stairs. Record you and your partners' times below.

Height of One Stair _________________ Height of Staircase _____________________

Your Time (seconds) ________________ Partners' Time (seconds) _______________

To make sense of how you are using energy to make it up the stairs, we want to use two values: **Work** and **Power**

To calculate how much work you had to do to get to the top of the stairs, use the

Work-Energy Theorem, which states that the work done on an object is equal to the change in energy of that object:

$$W = \Delta K = -\Delta U_g$$

or

$$W = K_f - K_i = U_i - U_f$$

Calculate the work you and your partner did to the stairs (remember g = **-** 9.8 m/s^2):

Work is also defined as the dot product of Force and Displacement:

$$W = \vec{F} \cdot \vec{d}$$

Where W is work in Joules

$\vec{F}$ is Force in Newtons

$\vec{d}$ is displacement in meters

Expanding the *Dot Product*, work can also be written like so:

$$W = |\vec{F}||\vec{d}|cos\theta$$

Where θ is the angle between the Force and Displacement vectors.

Find the angle of your displacement by finding the slope of the stairs and assuming you are applying force directly upwards.

What was the average force you had to apply to the stairs to climb them? Is this force greater or less than your weight? *Explain* why you think this is the case.

Did you and your partner do the same amount of work to get up the stairs? Why or why not?

Now we can determine the **Power** with which you climbed the stairs, which as defined as work done over a period of time.

$$P = \frac{W}{t}$$

Calculate the power you and your partner generated going up the stairs.

Did you and your partner do the same generate the same amount of power when going up the stairs?

From where did you get the energy you needed to generate power and do the work to climb the stairs?

Name ______________________________ Date___________

Biofuel Research Project

For this project, you will be researching the production, use, and efficiency of one type of biofuel. Begin by researching some of the different types of biofuels, then consider the following questions:

- From what organic matter is this biofuel derived?
- Is this a First, Second, Third, or Fourth Generation Biofuel?
- What processes are used to produce this biofuel?
- What is the energy density of this biofuel?
- Does this biofuel emit greenhouse gasses when used? If so, how many kilograms of CO_2 are produced per kilogram of biofuel?
- Can this biofuel be used with existing infrastructure, or does it require new infrastructure to be built?
- How expensive is it to produce this biofuel?
- Is this/will this biofuel be available directly to consumers? If so, how much does/will it cost to purchase?
- Is this biofuel currently being used in the United States or the world? If so, what percentage of energy production does it account for?
- Are there any drawbacks to using this type of biofuel?

After thoroughly researching your biofuel, prepare a presentation with the following components:

1. Introduce your Biofuel
2. Explain where your biofuel comes from and how it is made
3. Describe the physical or chemical structure of the biofuel, and how its combustion is used to release energy
4. Discuss the uses of your biofuel, or current research going into it
5. Discuss any drawbacks of your biofuel and explain whether or not you think it should be used more

Name ____________________________________ Date_______________

Work and Power Extension Problems

Refer to the tables below to complete the following problems.

Power Output for Various Activities

Activity	Estimated Power Required (Watts)
Basketball	800
Skating (4 m/s)	545
Swimming	475
Tennis	440
Cycling (4.2 m/s)	400
Walking (1.4 m/s)	265
Sitting while Focusing	210
Standing at Rest	125
Sitting at Rest	120
Sleeping	83

Resting Power Output by Human Organs

Organ	Estimated Power Required (Watts)
Liver and Spleen	23
Brain	16
Skeletal Muscle	15
Kidneys	9.1
Heart	5.6
Other	16

Both tables adapted from *Physics of the Body*

1. a. How much energy does your body use over a night if you get 8 hours of sleep?

ANS: W = P·t = 83 W · 28,800 s → **W = 2.39 x 10^6 J**

b. About how much of this energy is used by your brain?

ANS: W = P·t = 16 W · 28,800 s → **W = 4.61 x 10^5 J**

2. Suppose you want to go to a friend's house that is 3 km away.
   a. How long will it take you to walk to your friend's house if you walk at 1.4 m/s?

ANS: t = 3000 m / (1.4 m/s) → **t = 2140 s = 36 minutes**

   b. How much work must you do to walk to your friend's house?

ANS: W = P·t = 265 W · 2140 s → **W = 5.67 x 10^5 J**

   c. How long will it take you to cycle to your friend's house if you cycle at 4.2 m/s?

ANS: t = 3000 m / (4.2 m/s) → **t = 714 s = 11 minutes**

   d. How much work must you do to cycle to your friend's house?

ANS: W = P·t = 400 W · 714 s → **W = 2.86 x 10^5 J**

3. The human kidneys filter the entire body's volume of blood about 60 times per day.
   a. How much energy do the kidney's use over the course of a day?

      ANS: $W = P \cdot t = 9.1\ W \cdot\ 86400\ s \rightarrow$ **$W = 7.86 \times 10^5$ J**

   b. How much energy do the kidney's use to filter all of your blood?

      ANS: 7.86×10^5 J / (60) = **1.31×10^4 J**

   c. How many calories must you consume to meet the energy required by your kidneys to filter all of your blood once? (1 Calorie = 4184 Joules)

      ANS: 1.31×10^4 J = **3.13 Calories**

4. Use the table on the reverse side of this page to write about a day in which you complete at least four of the listed activities. Then, calculate the amount of energy needed to complete each activity. Finally, find a meal (or several meals) that would supply enough energy for you to complete each of the tasks.

Clean & Renewable Energy Learning Centers – Solar

Attach the photovoltaic cell to a voltmeter. Then, complete the following table to determine what factors may affect the power output of the solar cell. Note that the angle of incidence refers to the angle between the direction of the light and a vector perpendicular (normal) to the surface of the photovoltaic cell. Make sure to keep the distance between the PV Cell and the light source relatively constant between trials.

Light Source	Voltage at 0° Incident Angle (Volts)	Voltage at 45° Incident Angle (Volts)	Voltage at 80° Incident Angle (Volts)
UV Light			
Blue Light			
Red Light			
Green Light			
Flashlight			

Answer the following Questions:

1. How does the type of light change the energy output from the solar cell?
2. Find the wavelengths of blue, red, and green light. Do waves with longer wavelengths or shorter wave lengths carry more energy?
3. How does the incident angle of light change the energy output from the solar cell? Can you explain why this relationship makes sense?
4. How might the relationship between the incident angle of light falling on a solar cell and the energy output of the solar cell affect the placement of solar panels on a roof or field?

Clean & Renewable Energy Learning Centers – Wind

Wind: Attach the windmill base to a voltmeter. Then, design three blades out of construction paper to attach to the base. After attaching the blades to the base, record the voltage from the voltmeter on the blade itself. Now, redesign the blades to try to get the largest reading from the voltmeter. Record your groups largest voltage on the board and leave the blades at the front of the class.

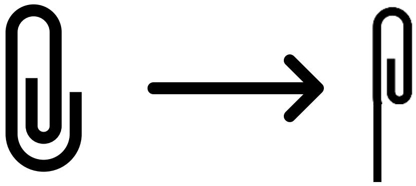
Answer the following questions:

1. How does the length of the blade affect the energy supplied by the windmill?
2. What blade shape resulted in the greatest reading from the voltmeter? Why do you think this was the case?
3. What blade shape resulted in the lowest reading from the voltmeter? Why do you think this was the case?

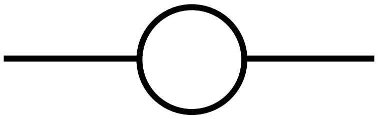
Clean & Renewable Energy Learning Centers – Chemical

Follow the steps below to construct a simple DC motor with a battery, two paperclips, a magnet, a coil of wire (partly frayed on one end) and rubber bands/tape:

1. Unfold two paperclips so that the large arm of each clip is straight (See the diagram below)



2. Using a rubber band or tape, attach the straight side of an unfolded paperclip to each side of the battery so that the paperclips are parallel to one another.
3. Attach a magnet to the center of the battery, in between the two paperclips.
4. Bend the wire at the center into a loop to make the shape below:



5. Rest the two arms of the looped wire in the arms of the paperclip. The motor is now complete, and the wire loop should be turning.

After constructing the motor, answer the following questions:

1. How does the speed of the motor change when the loop has more coils?

How does the speed of the motor change when a stronger magnet is placed on the battery?

Name________________________________ Date _____________

Sustainable Home Design

Your goal in this project is to design a home that utilizes active energy systems to generate electricity for the home and passive design elements in order to reduce the home's energy consumption.

With your group, choose a location in which you would like to plan for your home to be built.

Then, begin by researching some active energy systems and passive design elements such as the following:

Active Energy Systems	**Passive Design Elements**
Solar Panels	Building Layout & Orientation
Windmills	Ventilation
Geothermal Systems	Window Design/Natural Lighting
Hydropower systems	Shading
	Materials

Consider which systems will work best for your chosen location, then make an initial drawing of a home that utilizes at least 2 active energy systems and at least 3 passive design elements. In your drawing, make sure to use a color code with a legend to distinguish between different materials when necessary.

Along with your drawing, explain why you chose each energy system and design element and how they work well with the location you chose. For each active energy system, determine how much energy will be produced per month by researching the power output of the system and determining how many hours per day the system will be producing energy.

After your teacher/instructor has approved your drawing, you may begin to model your sustainable home using balsa wood, again color coding for different materials when necessary. Along with your model, write a letter to a prospective client explaining how each of the active energy systems and passive design elements work to produce energy and reduce energy consumption.

References

Ambrose, S. A., & Mayer, R. E. (2010). *How learning works: seven research-based principles for smart teaching*. San Francisco, CA: Jossey-Bass.

Armstrong, T. (2009). *Multiple intelligences in the classroom*. Alexandria, VA: ASCD.

Boden, T.A., Marland, G., and Andres, R.J. (2017). National CO2 Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-2014, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, doi 10.3334/CDIAC/00001_V2017.

Bohr, J., & Mccreery, A. C. (2019). Do Energy Burdens Contribute to Economic Poverty in the United States? A Panel Analysis. *Social Forces*. doi: 10.1093/sf/soz131

Budge, S. L., Thai, J. L., Tebbe, E. A., & Howard, K. A. S. (2016). The Intersection of Race, Sexual Orientation, Socioeconomic Status, Trans Identity, and Mental Health Outcomes. *The Counseling Psychologist*, *44*(7), 1025–1049.

Cameron, J. R., Skofronick, J. G., & Grant, R. M. (2017). Physics of the body. Madison, WI: Medical Physics Publishing.

Chen, C.-F., Tomsovic, K., & Aydeniz, M. (2014). Filling the Pipeline: Power System and Energy Curricula for Middle and High School Students Through Summer Programs. IEEE Transactions on Power Systems, 29(4), 1874–1879. doi: 10.1109/tpwrs.2013.2293752

Cook, J., Oreskes, N., Doran, P. T., Anderegg, W. R. L., Verheggen, B., Maibach, E. W., … Rice, K. (2016). Consensus on consensus: a synthesis of consensus estimates on human-caused global warming. *Environmental Research Letters*, *11*(4), 048002. doi: 10.1088/1748-9326/11/4/048002

Climatestrike.net (2019)

Denson, Stallworth, Hailey, & Householder (2014, November 30). Benefits of Informal Learning Environments: A Focused Examination of STEM-Based Program Environments. Retrieved from https://eric.ed.gov/?q=learning+environment&pr=on&id=EJ1065411

Department of Energy U.S. Energy and Employment Report; https://www.energy.gov/sites/prod/files/2017/01/f34/2017%20US%20Energy%20and%20Jobs%20Report_0.pdf: 2017

Dixson, D. D., & Worrell, F. C. (2016). Formative and Summative Assessment in the Classroom. Theory Into Practice, 55(2), 153–159. doi: 10.1080/00405841.2016.1148989

Feder, T. (2011). Convincing US states to require physics. *Physics Today*, *64*(7), 29–30. doi: 10.1063/pt.3.1163

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(23), 8410–8415.

Krause, S., Waters, C., Stuart, W., Judson, E., Ankeny, C., & Smith, B. (n.d.). Effect of Contextualization of Content and Concepts on Students Course Relevance and Value in Introductory Materials Classes. *2016 ASEE Annual Conference & Exposition Proceedings*. doi: 10.18260/p.26894

Lawson, D. F., Stevenson, K. T., Peterson, M. N., Carrier, S. J., Strnad, R. L., & Seekamp, E. (2019). Children can foster climate change concern among their parents. *Nature Climate Change*, *9*(6), 458–462. doi: 10.1038/s41558-019-0463-3

Mazzolini, A., Daniel, S., & Edwards, T. (2012). Using interactive lecture demonstrations to improve conceptual understanding of resonance in an electronics course. Australasian Journal of Engineering Education, 18(1). doi: 10.7158/d12-004.2012.18.1

Next Generation Science Standards. (2019, December 20). Retrieved from https://www.nextgenscience.org/

Plutzer, E., Mccaffrey, M., Hannah, A. L., Rosenau, J., Berbeco, M., & Reid, A. H. (2016). Climate confusion among U.S. teachers. *Science*, *351*(6274), 664–665. doi: 10.1126/science.aab3907

Public High School Graduation Rates. (2019, May). Retrieved from https://nces.ed.gov/programs/coe/indicator_coi.asp

Saad, L. (2019, September 4). Americans as Concerned as Ever About Global Warming. Retrieved from https://news.gallup.com/poll/248027/americans-concerned-ever-global-warming.aspx

Sawyer, K. R. (2006). The Cambridge Handbook of The Learning Sciences. Cambridge: University Press.

Schnittka, Christine G., Brandt, Carol B., Jones, Brett D. & Evans, Michael A. (2011, November 30). Informal Engineering Education after School: Employing the Studio Model for Motivation and Identification in STEM Domains. Retrieved from https://eric.ed.gov/?id=EJ1076077

Şen, H. C. (2010). An aptitude treatment interaction study: the effect of inquiry based instruction and lecture instruction on high school students' physics achievement. *OpenMETU*.

Solar Industry Diversity Study. (2019). Retrieved from https://www.thesolarfoundation.org/diversity/

STEM 2026: A Vision for Innovation in STEM Education. (2016). Retrieved from https://www.air.org/system/files/downloads/report/STEM-2026-Vision-for-Innovation-September-2016.pdf

White, S. C. (2015). Underrepresented minorities among physics family members. *The Physics Teacher*, *53*(1), 37–37. doi: 10.1119/1.4904241

Wiggins, G., & Mctighe, J. (2013). Understanding by Design, Expanded 2Nd Edition. ASCD.

Xie, Y., Fang, M., & Shauman, K. (2015). STEM Education. *Annual Review of Sociology*, *41*(1), 331–357. doi: 10.1146/annurev-soc-071312-145659

YouthStats: Environment and Climate Change - Office of the Secretary-General's Envoy on Youth. (2011). Retrieved from https://www.un.org/youthenvoy/environment-climate-change/

Zownorega, S. J. (2013). Effectiveness Of Flipping The Classroom In A Honors Level, Mechanics-Based Physics Class. *Eastern Illinois University*.