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Use of Modeling to Support Students’ Learning of Energy Concepts

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By

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Introduction

There is no doubt that science has a reputation for being a fun, but challenging subject to teach. Science requires abstract and critical thinking skills that students may not have developed yet. Naturally, students are concrete thinkers and often have a hard time understanding concepts that they cannot physically see. Due to this, teachers have had to come up with effective ways to teach science concepts. Arguably the most effective way to teach science would be to incorporate modeling into lessons. According to the Framework, "Scientists use models to represent their current understanding of a system (or parts of a system) under study, to aid in the development of questions and explanations, and to communicate ideas to others" (National Research Council 2012, p. 57). Modeling is a way for students to demonstrate their learning through creation. Models help students visualize and observe concepts.

Energy: Speed, Potential, and Kinetic Energy

The lesson outlined in this paper focuses specifically on teaching concepts of speed and its impact on energy, as well as providing a basic introduction to potential and kinetic energy to 4th-grade students. Next Generation Science Standard 4-PS3-1 states that students should be able "to use evidence to construct an explanation relating the speed of an object to the energy of that object" (NGSS Lead States 2013). Our lesson connects to the NGSS Cross Cutting Concept, Energy and Matter, which states that the transfer of energy can be tracked as energy flows through a designed or natural system.

Energy comes in many forms, including motion, light, sound, electricity, magnetic fields, and heat (thermal energy). In this lesson, we chose to focus on motion, or kinetic energy. Kinetic energy is the energy of motion; before that motion occurs, the energy is stored as potential energy. The faster an object moves, the greater the level of kinetic energy held by the object. For example, in a standard spring, potential energy is increased the more the spring is compressed (squeezed together). Once a person lets go of the spring, the potential energy is transformed to kinetic energy when the spring moves. The tighter the compressions (force), the faster the spring goes, and the greater the level of kinetic energy. Scientifically, kinetic energy is measured as the velocity of the object squared.

This lesson starts off with an introduction and discussion to get students thinking about energy. Starting with discussion questions can also help students build from their prior knowledge and connect personal experiences to their learning. Questions we started with included, "What is energy?", "Can we see energy?", "How do we know that energy exists if we cannot see it?" These open-ended type questions allow students to think deeper at a higher level of understanding. These types of questions can also be answered with multiple answers, and they allow the teacher to see a student's thought process and what they understand or need help with. Some answers one might expect to get from students can vary. Students may say that energy is moving or when something is moving. Another common answer that students at this age may give is listing things that have energy such as cars, batteries, and people. Students may present misconceptions where they believe that energy is a magical element that forms from air or electrical currents. It is easy to come up with real-life examples where potential and kinetic energy is demonstrated; however, people cannot see energy and students may have a hard time comprehending it.

Engage

For this lesson, we are looking at speed, potential energy, and kinetic energy in real-life scenarios. To start the lesson, we asked students to imagine that they were learning to skateboard or ride a bike (interests of our students). We then showed them two "hills" drawn on the board, one with a slow decline, and the other with a steep decline. We asked the students which hill they would prefer to learn on, and why. Many of the students were adamant that the hill with a slower decline would be the best hill to learn on, "so you don't get going too fast and get hurt!" We asked them how they knew that someone would get hurt on a steeper hill. The students explained that the faster they go, the harder they fall, and the more likely they to be injured. Some shared comparative examples from playing with their toy cars or video games, where the faster the vehicle, the greater the impact of a collision. We asked the students to consider the relationship between the speed of the object and the amount of energy it possesses. The students shared that they thought that the faster the object, the more energy it would have. We explained to the students that potential energy is energy that is stored, while kinetic energy is energy in motion, and that they were correct - the greater the speed, the greater the amount of kinetic energy possessed by the object.

Explore:

To explore speed, kinetic energy, and potential energy, the students were then divided into groups of four or five to work in stations. We chose to group our students based on their understanding, with those needing more support grouped together, and those further along grouped together. For this phase of the lesson, there were four workstations. Before starting all the stations, students were given a data collection sheet (See Supplementary File 1 for student data collection sheets). Students performed each activity at the workstation and filled out the data collection worksheets. During these workstations, students were expected to be able to point out potential energy and kinetic energy and how force and speed influence the amount of kinetic energy. These expectations were enforced through the data collection worksheets because they had to talk about the workstation and identify where there is potential and kinetic energy with each activity. Students were able to point these forms of energy out by discussing their observations on their data collection sheets. Students spent approximately five to seven minutes at each station.

The first workstation was a balloon release (See Image 1). At this station, students used only a balloon. For this workstation, students were reminded to wear safety goggles as a precaution. Students were reminded to not aim the balloon at their peers while conducting their investigation. Students filled the balloon with air and held it so that the air did not come out. Students then released the balloon. Students explained that when holding the balloon filled with air, it had potential energy, and then when they let it go, it had kinetic energy. They also tested to see if releasing the balloon quickly or slowly would impact the amount of energy that the balloon had as it released the air.

The second workstation included a toy bow and arrow, as well as a target (see Image 2). Students wore safety goggles as a precautionary measure and were again instructed to only point the arrow at the target. This station was done outside, to ensure student safety, and with a toy bow and arrow with a blunt tip. Students aimed the bow towards a target and released the arrow. As students worked with the toy bow and arrow, they were able to play around with the speed. Students documented that the more they drew the bow, the more potential energy it would have, and in relation, when it was released, there was an increase in the kinetic energy as well, sending the arrow further. Students were able to document this on their data collection sheets.

The third station consisted of a ball on a hill (see Image 3). Students used a track (created from a foam insulation tube for a plumbing) that has a hill and a marble to explore energy. Students placed the marble on top of the “hill” and then released it to go down the track. Students explained that when the marble is at the top of the hill, it has potential energy, and when the marble is released, it has kinetic energy. Students may also point out that if the hill is steeper, the object will roll down it faster, thus having more kinetic energy,

The fourth station was a swinging pendulum (see Image 4). Students created the pendulum with a meter stick, tape, string, and a small weight. The meter stick was taped down between two desks. The string was tied to the meter stick on one end and to the weight on the other. Students pulled the weight towards them and released it, watching the weight swing back and forth. Students explained that when holding the weight, it has potential energy and when they release it, it will have kinetic energy. In conjunction, if the ball is released from a grander height, it will have more speed and kinetic energy when it is released.

Explain:

Once students completed the workstations, we came together as a class to share our findings. Each group was asked to share their observations and identification of the potential and kinetic energy from one workstation, with the other groups listening and indicating whether they agreed or disagreed with the group’s findings. As groups shared, we informally assessed their abilities to correctly identify the kinetic and potential energy in each scenario, as well as whether their peers agreed or disagreed. The groups also noted that the amount of speed can influence the amount of kinetic energy. One group explained how in the second workstation, with the bow and arrow, the amount of speed influenced how much kinetic energy the object would possess. They were able to conclude that objects with more kinetic energy have more power. Another group noted that while they were at the third station, the ball on the hill, they were able to see that the steeper the hill, the faster the marble would roll down, which increased the kinetic energy in the marble, and if they flattened the hill more, the marble would go slower, thus not having as much kinetic energy.

Elaborate:

After students had the opportunity to examine energy using the workstations, we took students outside to find more real-life examples in one of their favorite locations - the playground! Students were asked to identify as many places as they could see potential and kinetic energy and to record their findings on the second page of their data collection sheet. Students recorded their findings on the datasheet, including locations such as the swings, the slide, and where kids were playing four-square. Additionally, students were required to take pictures of one site through multiple stages - for example, a student at the top of the slide (potential energy), going down the slide (kinetic energy), and sliding quickly and slowly. The students were encouraged to see how speed impacted energy levels. For example, when students pushed the ball harder, it moved faster toward their opponent in the four-square game. After collecting their data, students brought it back inside to work on a poster demonstrating their understanding of energy.

Evaluate:

To assess student learning, the student posters were graded using a rubric (see Supplementary File 2). On this poster, students were required to include pictures that they took from the outdoor activity, definitions of kinetic and potential energy, and examples of each, but could also include other pictures or text to help get their thoughts across. While working, students were provided with copies of the assessment rubric so that they would know exactly what is expected of them. Our class worked on this project for three days. They researched and started making a poster or model one day and finished it the next two days. However, you can adapt the project requirements and length to your own classroom.

Considerations for Adaptation

If the lesson is intended for a different grade level, it can be easily adapted. The workstations can be adapted to be more in-depth and require little to no supervision. This lesson can also be adapted to meet the needs of all students. For example, there are components in each workstation that cater to students who learn visually, auditorily, or tacitly (hands-on). All the workstations are hands-on activities that allow students to visualize and manipulate materials to understand what they are learning. Prior to sending the students to complete the activities, it may be helpful to read all the instructions for the workstations and explain to students how to complete them. The students are also able to learn through hearing other opinions, ideas, and conclusions from their peers and the teacher. Students should be given all materials to complete the workstations. The teacher may also opt to complete just one workstation with the class and focus on the components of that one activity. The materials found in this lesson are low cost or can already be found in classrooms/schools, allowing greater access for students.

The experience students will get out of this lesson and its many components will allow them to fully process and understand the differences between kinetic and potential energy as well as the transfer of energies. This lesson hones in on the importance of modeling as a way for students to demonstrate their learning through creation. Students are given an introduction and brief directions before they are sent to the workstations where they are creating and manipulating materials to help them visualize and observe scientific concepts. Modeling is a powerful method for teaching science concepts to children, and in this lesson on energy, it has proven to be very effective in supporting student success.

References

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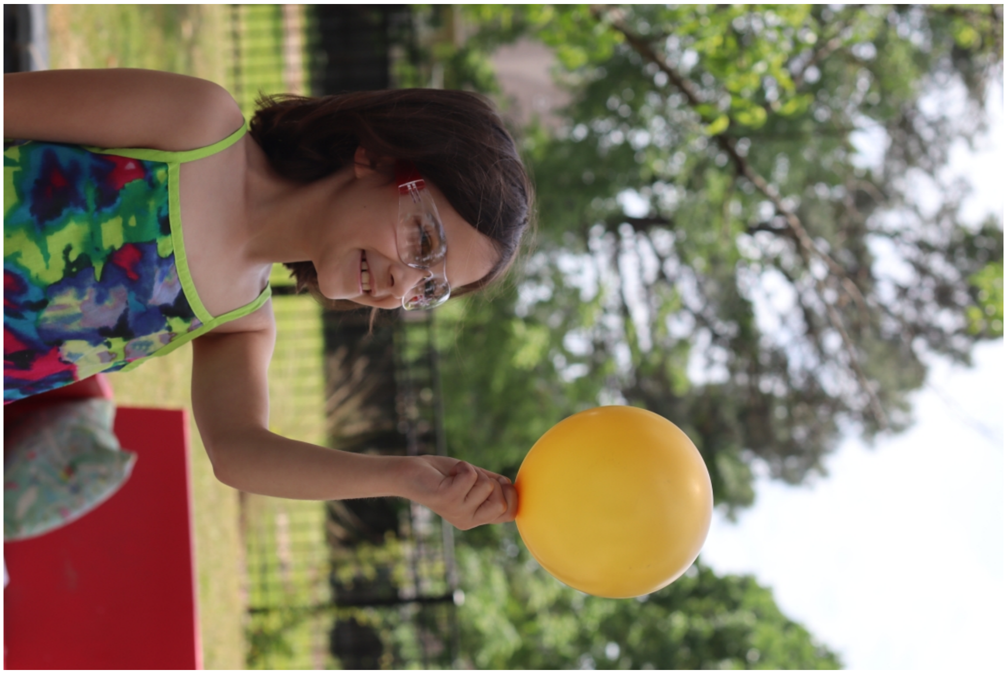
Supplementary File 1: Student Data Collection Sheet

Name:______________________

Energy Worksheet

Workstation	Observe what happened and what you did at this station	Where is kinetic energy?	Where is Potential Energy?
Balloon Release			
Bow and Arrow			
Ball on a hill			
Swinging Pendulum			

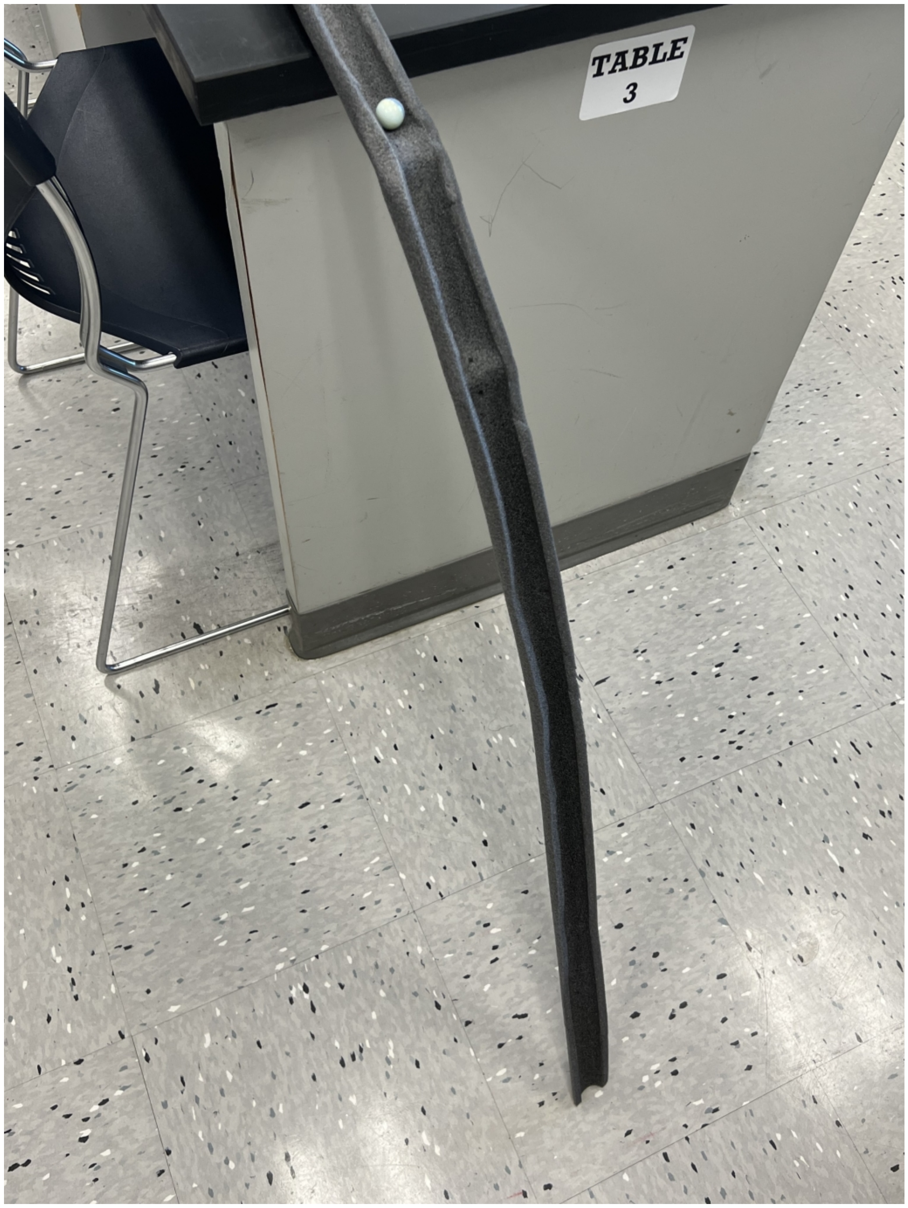


A student uses a balloon to identify potential and kinetic energy.

2116x1411mm (72 x 72 DPI)

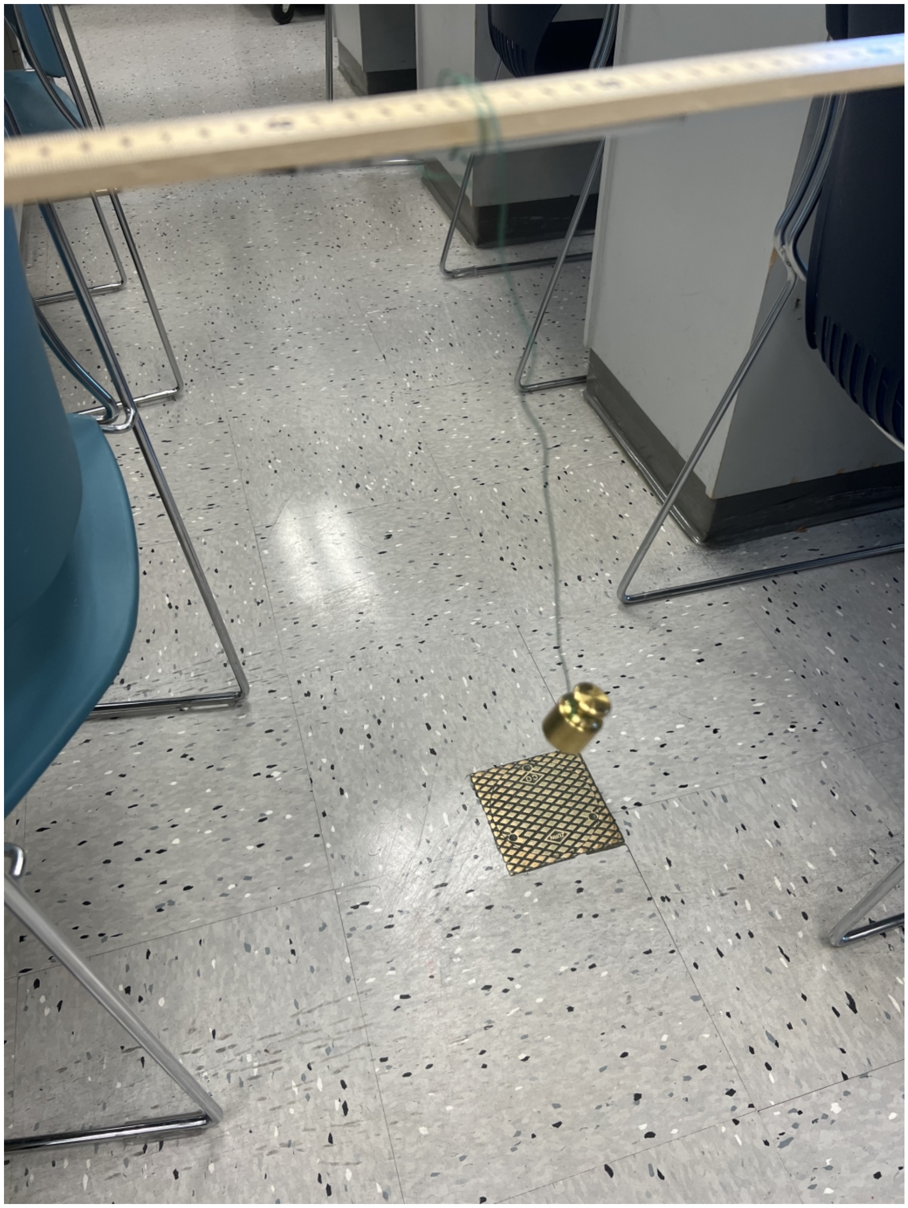
A student uses a toy bow and arrow to identify potential and kinetic energy.

2116x1411mm (72 x 72 DPI)



Marble ramp made by students to identify potential and kinetic energy.

1066x1422mm (72 x 72 DPI)



Pendulum made by students to demonstrate potential and kinetic energy.

1066x1422mm (72 x 72 DPI)

Supplementary File 2: Poster Rubric

Group Members:

Kinetic and Potential Energy Poster Rubric

Category	1	2	3	4
Use of Class Time	Group did not use class time to focus on the task.	Group used some of the class time to focus on the task but mostly did not work.	Group used most of the class time to work and was fairly focused.	Group used all class time to work and was focused the whole time.
Collaborative Working	Group members did not work together and/or left someone out.	Group members worked together a little bit.	Group members worked together for most of the time.	Group members worked together effectively to complete the task.
Graphics/Visual Appeal	Poster did not include pictures or have any visual appeal.	Poster included one or two pictures or some coloring but not much.	Poster included some variety of pictures and visual appeal.	Poster was fun to look at; it included many pictures, different colors, and text.
Information and Accuracy	Group did not include definitions of kinetic and/or potential energy.	Group included definitions of kinetic and potential energy, but they were inaccurate.	Group included brief definitions of kinetic and potential energy.	Group included definitions of kinetic and potential energy, with examples of each.

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

Standard

4-PS3-1: Use evidence to construct an explanation relating the speed of an object to the energy of that object

https://www.nextgenscience.org/pe/4-ps3-1-energy

The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.

Dimensions	Classroom Connections
Science and Engineering Practices	
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems. ● Use evidence (e.g., measurements, observations, patterns) to construct an explanation.	● Students analyze the transfer of energy by observing various activities in stations. The students will write their observations and their explanations on how the energy is transferred.
Disciplinary Core Ideas **PS3.A: Definitions of Energy** ● The faster a given object is moving, the more energy it possesses.	● Students will observe and analyze how the faster an object is moving the more energy it possesses through the use of stations.
Crosscutting Concepts	
Energy and Matter ● Energy can be transferred in various ways and between objects.	● Students will observe and analyze the different ways energy can be transferred between objects through the use of the stations. ○ Station #1- students will observe the transfer of energy when the balloon is released. ○ Station #2- students will observe the transfer of energy when the bow is pulled back compared to when it is released. ○ Station #3- students will observe the

	transfer of energy from when the ball is stationary at the top of a hill compared to when it is rolling down the hill ○ Station #4- students will observe the transfer of energy between the balls of the swinging pendulum.
Building Towards **Performance Expectation (PE listing with Clarification Statement and Assessment Boundary)** 4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object. [Clarification Statement: Through observing and analyzing evidence, students should recognize that the faster a given object is moving, the more energy it possesses and that energy can be transferred in various ways and between objects.] *Assessment Boundary: Assessment does not include quantitative measures of changes in the speed of an object or on any precise or quantitative definition of energy.*	