Investigative Phenomenon

Record observations. I noticed……..

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Make a prediction

What topic of study or content do you think this phenomenon activity is introducing?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
#1 Start with the standard

Students who demonstrate understanding can:

**MS-PS3-2.** Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. [Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate’s hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.] [Assessment Boundary: Assessment is limited to two objects and electric, magnetic, and gravitational interactions.]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education:*

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing and Using Models</td>
<td>PS3.A: Definitions of Energy</td>
<td></td>
</tr>
<tr>
<td>Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems.</td>
<td>- A system of objects may also contain stored (potential) energy, depending on their relative positions.</td>
<td></td>
</tr>
<tr>
<td>• Develop a model to describe unobservable mechanisms.</td>
<td>PS3.C: Relationship Between Energy and Forces</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.</td>
<td></td>
</tr>
</tbody>
</table>

**Connections to other DCIs in this grade-band:** N/A

**Articulation of DCIs across grade-bands:**

**Common Core State Standards Connections:**
- ELA/Literacy - SL.8.5
  - Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-PS3-2)
#2 Unpack the three dimensions

The Standard

| Performance Expectation | **MS-PS3-2**: Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.  
Clarity and Precision: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate’s hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems. |
|------------------------|----------------------------------------------------------------------------------------------------------|
| DCI                    | **PS3.A**: Definitions of Energy  
**PS3.C**: Relationship Between Energy and Forces |
| CCC                    | Systems and System Models |
| SEP                    | Developing and Using Models |

#3 Read the Evidence Statement to find out how you will get your students to demonstrate the PE proficiently
Evidence statements were written to guide the development of instructional activities and the development of three-dimensional assessments.

The Evidence Statement

Observable features of the students’ performance by the end of the course:

<table>
<thead>
<tr>
<th></th>
<th>Components of the model (practice #2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>To make sense of a given phenomenon including two objects interacting at a distance, students develop a model in which they identify the relevant components</td>
</tr>
<tr>
<td></td>
<td>• A system of two stationary objects that interact.</td>
</tr>
<tr>
<td></td>
<td>• Forces (electric, magnetic, or gravitational) through which the two objects interact.</td>
</tr>
<tr>
<td></td>
<td>• Distance between the two objects.</td>
</tr>
<tr>
<td></td>
<td>• Potential Energy</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Relationships within a model (practice #2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>In a model, students identify and describe relationships between components</td>
</tr>
<tr>
<td></td>
<td>• When two objects interact at a distance, each one exerts a force on the other that can cause energy to be transferred to or from an object.</td>
</tr>
<tr>
<td></td>
<td>• As the relative position of two objects (neutral, charged, magnetic) changes, the potential energy of the system (associated with interactions via electric, magnetic, and gravitational forces) changes.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Students use the model to provide a casual account for the idea that the amount of potential energy in a system of objects changes when the distance between stationary objects interacting in the system changes</td>
</tr>
<tr>
<td></td>
<td>• Because a force has to be applied to move two attracting objects farther apart, transferring energy to the system.</td>
</tr>
<tr>
<td></td>
<td>• Because a force has to be applied to move two repelling objects closer together, transferring energy to the system.</td>
</tr>
</tbody>
</table>

#4 Develop a Summative Assessment
- End project with rubric
- Test - with SEP driven tasks, based on a scenario and data

Sample Project:
Balloon Car

PBL Entry Document

Build and Learn Toy Company manufactures educational toys that are fun and entertaining. They are looking for a toy car product design that can be sold as a you-build-it car kit. Research from the marketing team shows that certain attributes appeal to kids and would potentially improve sales. Balloons, always popular and fun, will provide the force needed to accelerate the toy. The construction of the toy should be easy to build and use simple everyday materials. The balloon-powered car should move fast, go a long distance, and look really cool.

You will be part of a team of experts who will provide different perspectives on the design and construction of the balloon-powered car. These experts include a Project Manager, a Mechanical Engineer, an Automotive Designer, and a System Operator.

Your team will make a poster-sized design sketch and create an initial material list. Then your team will build and test the prototype, redesigning and testing as necessary to meet the criteria.

For your prototype to be considered for review, you must provide a poster that includes the original sketch and specifies all changes due to redesign. Identify at least three components of the prototype and explain how each one:

- shows a relationship between force, mass, and acceleration, OR
- demonstrates the effect of balanced/unbalanced forces on an object.

An instruction manual must accompany the prototype that contains:
1. An accurate material list
2. Instructions for building the car – a series of ordered steps.
3. How to operate the car
4. A data log of test results.
5. Designs and presentations that do not meet these requirements will not be accepted for consideration.

You will present your product design and other required items to a panel of representatives from the Build and Learn Toy Company. Your presentation is limited to 10 minutes. In that time, you are to present your poster, instruction manual, and demonstrate the prototype. Remember to use test result data in your presentation to convince the toy company representatives that your team understands how redesigning relates to balanced/unbalanced forces and relationships between force, mass, and acceleration. Be enthusiastic so you can sway the representatives to select your design. Additional consideration will be given to the team that demonstrates a way to easily modify the car and can explain how the modification results in a specific change of motion due to an identified relationship between force, mass, and/or acceleration.
Balloon Car

Name: ___________________  Date: __________

PBL Expert Roles

Project Manager Role
The Project Manager is the design team leader. It is important for you to be mindful of the constraints as well as keeping your team on track to meet the criteria for a completed product. Rubrics will help you to keep your team on target with the many tasks that will need to be accomplished in a short time. Keep in mind the 21st Century Skill of Innovation that will be evaluated specifically.

Mechanical Engineer Role
You are responsible for determining acceleration changes and balanced/unbalanced forces that are affected by the design and operation of the balloon-powered car. You create the step-by-step list of instructions for the car’s construction. You are the consultant for your team in knowing how to adjust the prototype design to meet the criteria. You will be sure that notes supporting design changes are recorded on the poster. You will share your findings along with your team in the final presentation.

Automotive Designer
You are responsible for researching and drawing the poster-sized sketch for the prototype. Your poster must accurately show the details of the team’s original design. You also include information on the poster to identify redesigned elements with supporting reasoning for the changes. A poster and markers will be available for your drawing. You and all of your team members present the final design plan along with the reasoning for decisions made.

System Operator
You are responsible for creating an accurate material list and a step-by-step list for how to operate the car. You are responsible for operating the prototype during testing and the presentation. You maintain the team’s written data log of test results. The team will use the data to support redesign claims resulting from factors affecting balanced/unbalanced forces and acceleration changes. You and your team use this information in the presentation to convince the representatives that your team’s design should be chosen.
## Balloon Car

**Rubric for a Problem/Project-Based Learning Challenge**

<table>
<thead>
<tr>
<th>Points Awarded</th>
<th>Expert (4)</th>
<th>Competent (3)</th>
<th>Beginner (2)</th>
<th>Novice (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Identification of Problem and Constraints</strong></td>
<td>Clearly defines the problem in real-world context and identifies the criteria in the solution. Meets time limit for presentation.</td>
<td>Defines the problem and the criteria within the context presented.</td>
<td>Identifies the problem and does not address the criteria.</td>
<td>Problem is not clearly identified and/or few criteria are addressed.</td>
</tr>
<tr>
<td><strong>Solution, Prototype, or Plan</strong></td>
<td>Prototype demonstration includes relationship between three design components and changing acceleration or balanced/unbalanced forces. Meets time limit for presentation.</td>
<td>Prototype is complete. Presentation of prototype missing 1-2 requirements. Meets time limit for presentation.</td>
<td>Prototype is incomplete. Presentation of prototype missing requirements. Slightly over or under time limit.</td>
<td>Prototype is incomplete. Presentation of prototype missing requirements. Well over or under time limit.</td>
</tr>
<tr>
<td><strong>Design Details Poster</strong></td>
<td>Poster is neat and complete. Reasoning for redesigned elements is clearly stated during the poster presentation.</td>
<td>Poster is neat and nearly complete. Reasoning for redesigned elements is present but not thorough.</td>
<td>Poster is missing 1-2 pieces of information.</td>
<td>Poster is sloppy and missing more than two pieces of information.</td>
</tr>
<tr>
<td><strong>Instruction Manual</strong></td>
<td>Manual is neat and complete. Reasoning is thorough, and data from test results are used as evidence to support design changes during the presentation.</td>
<td>Manual is complete. Reasoning is clear but not thorough.</td>
<td>Manual missing 1-2 pieces of information.</td>
<td>Manual missing more than two pieces of information.</td>
</tr>
<tr>
<td><strong>Scientific Content shows depth in understanding and is applicable to the solution of the problem.</strong></td>
<td>Presentation of prototype, instruction manual, and design poster shows understanding of balanced/unbalanced forces and causes of acceleration change.</td>
<td>Presentation of prototype, instruction manual, and design poster shows understanding of balanced/unbalanced forces and causes of acceleration change.</td>
<td>Presentation of prototype, instruction manual, and design poster does not show an understanding of balanced/unbalanced forces and causes of acceleration change.</td>
<td>Presentation of prototype, instruction manual, and design does not address or discuss the effects of balanced/unbalanced forces or causes of acceleration change.</td>
</tr>
</tbody>
</table>
Sample Test

Scenario

In a pinball machine, a ball, usually steel, moves through a game board. The object of the game is to keep the ball in play to gain as many points as possible before the ball falls through the hole at the bottom. To begin the game, you pull back a lever with a spring and shoot the ball onto the board. Typically, the farther you pull back the spring, the farther and faster the ball goes. Also, there are pieces called flippers that you can manipulate to try to keep the ball from falling into the hole.

External Data

Write a scientific explanation that explains which lever position would start the game with the most potential energy.
#5 Develop Formative Assessments

- Design three dimensional instructional activities
- Prepare your students to demonstrate the standard
- Formatively assess their progress as they complete various activities

Instructional Activities Using the 5E Instructional Model

Activity #1
Rubber Band Energy

Vocabulary discussed prior to the activity:
- Energy
- Force
- Potential Energy
- Kinetic Energy

![Rubber Band Energy Activity](image)

<table>
<thead>
<tr>
<th>Stretch (cm)</th>
<th>Distance Traveled (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 cm</td>
<td></td>
</tr>
<tr>
<td>15 cm</td>
<td></td>
</tr>
<tr>
<td>___ cm</td>
<td></td>
</tr>
</tbody>
</table>

6. What connection do you notice between stretching the rubber band and the distance it flew across the room?
Activity #2
Potential Predictions

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**Explore**

**Name:** ____________________________  
**Date:** ____________

**Potential Predictions**

The force of gravity can cause objects within a system to interact. The mass of the objects and distance between them are the variables that control how much gravitational potential energy is stored in the system.

Consider an apple hanging on a tree several meters above Earth’s surface. The apple and Earth make up a system. The apple stores potential energy because of its position above Earth’s surface. The apple has the “potential” to fall, so it has gravitational potential energy.

When the apple falls from the tree, its potential energy transforms into kinetic energy, causing it to fall faster and faster until it strikes the ground. A system’s energy equals its potential energy plus its kinetic energy and the total does not change as the apple falls. When the apple is still in the tree, the energy of the system is 100% potential. The moment it has fallen halfway down, the system’s energy is 50% potential and 50% kinetic. The moment just as the apple is about to strike the ground, the system’s energy is almost 100% kinetic.

**Procedure:**

Plan an investigation to explore potential energy by holding a ball above Earth’s surface and then dropping it from different heights.

**Question:**

**Hypothesis:**

**Materials:**

1 Bouncy ball
1 Meterstick

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Procedures and Data:

Record the steps you will take in this investigation and your data below.
Crosscutting Concepts - Scoring Rubric

MS-PS Grade - Bundle 4: Potential and Kinetic Energy

Scope: Potential Energy

4) Systems & System Models

Models can be used to represent systems and their interactions - such as inputs, processes and outputs - and energy and matter flows within systems.

Artifact

Evaluate the student’s response to the following prompt.

“What were you able to model in your investigation? What did you learn about the system involving the earth and a falling object?” (Explore 1) “What did you learn about the system involving charged objects?” (Explore 2)

Novice

Novice: A student at the novice level is able only to describe the simple mechanics of their investigation.

Representative Novice Responses:
- We dropped a ball from different heights.
- We gave a charge to a balloon by rubbing it.

Emergent

Emergent: A student at the emergent level can describe how their model relates to potential energy and the interactions within a system.

Representative Emergent Responses:
- We modeled the system of potential energy and how it changes. We dropped a ball from different heights and watched it bounce to see how potential energy changes.
- We modeled the system of electrical potential energy and how it changes. We rubbed a balloon more to give it more charge (potential energy) and observed how it attracted paper.

Proficient

Proficient: A student is proficient if they can describe in detail how their investigation models the system of potential energy involving the earth and an object.

Representative Proficient Responses:
- We modeled the system of potential energy and the factors that affect that system. We dropped a ball from different heights and watched it bounce to see how potential energy changes. As we increased the height we dropped the ball from, we saw that it had more potential energy.
- We modeled the system of electric potential energy and the factors that affect that system. By rubbing the balloon more times with wool we gave it more potential energy and it could pick up paper from farther away.
**Science & Engineering Practices - Scoring Rubric**

**MS-PS Grade - Bundle 4: Potential and Kinetic Energy**

**Scope: Potential Energy**

2) Developing & Using Models

*Develop a model to describe unobservable mechanisms.*

**Artifact**

Evaluate the student's response to the following prompt.

"Describe what you learned about potential energy from one activity. How did the activity provide information to help you reach this understanding?" (Explore 1, Explore 2)

**Novice**

Novice: A student at the novice level is unable to offer a reasonable response.

**Representative Novice Responses:**
- I don’t know.
- We learned how potential energy changes.

**Emergent**

Emergent: A student at the emergent level describes an activity or a conclusion about potential energy, but can’t relate them to each other.

**Representative Emergent Responses:**
- We saw that a ball bounces higher if you drop it from higher.
- We saw how if something has more potential energy, it can do more work.

**Proficient**

Proficient: A student is proficient if they can describe a conclusion and connect it to the model they observed in class.

**Representative Proficient Responses:**
- We learned that the higher you lift an object, the more potential energy it has from the pull of gravity. We learned this by dropping a ball from higher and higher and watched how it bounced.
- We learned that the more electrical potential energy an object has, the more it can attract something. We learned this by rubbing a balloon with wool to give it an electric charge so it could pick up small pieces of paper. The more we rubbed the balloon, the more energy it had and it could pick up the paper from farther away.