NGSS Explorations of Forces & Motion in the Elementary Classroom

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Presentation Abstract:

We will explore engaging activities designed to help students understand and explore the effects of balanced and unbalanced forces on the motion of an object.

Educational Goal:

Our models of balanced and unbalanced forces are based on the premise that children construct their knowledge by building on or modifying the understandings they already have in place. Furthermore, it is also recognized that children are more apt to learn and remember what they learn when the learning experiences are immediate and meaningful to them. Our investigation will lead children to realize that when forces are balanced, there is no movement. Conversely, when forces are not balanced, there is movement. Furthermore, our investigation will give students a better understanding as to what forces act upon objects.

Next Generation Science Standards:

The workshop that is being presented today can be modified in many ways to accommodate the grade level and cognitive ability of your students.

Regardless of how you modify your investigation, it is quite certain that your investigation will address the physical science strands found in the Next Generation Science Standards.

Here are some examples found in the standards in Grade 3:

- **3-PS2-1.** Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.
- **3-PS2-2.** Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

Here are some examples found in the standards in Grade 4:

- **4-PS3-1.** Use evidence to construct an explanation relating the speed of an object to the energy of that object.
- **4-PS3-3.** Ask questions and predict outcomes about the changes in energy that occur when objects collide.

Workshop Outline:

I. How comfortable are you with basic physics concepts?
A) Background Information: The basics of forces & motion.
B) What are some of the most important big ideas and what are some misconceptions?

II. How do your investigations of balanced & unbalanced forces fit into the big picture?
A) What are the learning expectations of prior grades?
B) How are your investigations providing the building blocks for later grades?

III. What are some investigative ideas to help your students understand the effects of balanced & unbalanced forces?
A) Student Investigations utilizing laboratory simulations found on the web.
B) Student Investigations utilizing actual physical evidence in the lab.

IV. How do we have students actually develop their own investigations that explore concepts of motion and forces? What are some investigative ideas to help your students understand the effects of balanced & unbalanced forces?
A) Teacher brainstorming session with provided equipment.

Background Information: The following 2 pages of background information is taken from The Forces & Motion Activity Tub that comes from lakeshorelearning.com

The Basics of Force & Motion

A **force** is a push or a pull. Much of what we know about forces and their resulting motions comes from the ideas of Sir Isaac Newton. A mathematician and scientist, Newton lived in England during the 1600s. He published his observations and theories about force and motion in 1687. Even though Newton's document is now hundreds of years old, the three "laws" he presented are still the foundation of modern physics. To explore force and motion, we need to understand Newton's three laws and be able to identify them in the world around us.

Newton's First Law of Motion

- **An object at rest tends to stay at rest, and an object in motion tends to stay in motion, unless acted upon by an outside, unbalanced force.**

Newton's First Law basically argues that objects—whether they are staying still or moving—tend to keep on doing what they're doing until something interferes. When we put something down, it tends to stay in that spot until someone or something moves it. The second part of this law—that a moving object will stay in motion—is more difficult to grasp. It's hard to picture an object in motion forever since moving objects always seem to slow down at some point.

When objects slow down or stop moving, it's always due to an outside force, like friction or air resistance. **Friction** occurs when two objects rub against each other. As a skier moves over the snow, the contact between the skis and the snow creates **sliding friction**. An object (like a skateboard) rolling over a surface creates **rolling friction**.

Newton's First Law is also called the "law of inertia." **Inertia** is another word to describe an object's tendency to stay in motion or at rest unless an outside force interferes.

Balanced and Unbalanced Forces

Newton's First Law of Motion assumes that the forces acting on the object are **balanced**. When a book is at rest on a table, the force of gravity pushing down on the book is equal to the force of the desk pushing up. The forces acting on the book are balanced, so the book stays put. The same is true of objects in motion. If the forces acting on a moving object are balanced, and no other outside forces interfere, the object would keep on moving forever.

Unbalanced forces cause a change in position or motion. If two people are arm wrestling and both exert the exact same amount of force, their arms will be deadlocked in the same spot. The balanced forces cancel each other out, causing a state of **equilibrium** where there is no motion or change. As soon as one person exerts more force, the forces become unbalanced. Unbalanced forces always result in motion. In the case of the arm wrestling, the stronger arm will overtake the weaker arm and push it down.

Once an object is set into motion, we can measure how fast it travels and calculate its **speed**. We can also calculate the **velocity**, which describes the speed and direction of a moving object. If the moving object travels at the same, unchanging velocity, it has a **constant** speed. A change in velocity (speeding up) causes **acceleration**.

Newton's Second Law of Motion

- **Acceleration of an object depends on the force and mass.**

While Newton's First Law describes how objects behave when forces are balanced, his second law is about what happens when two forces are unbalanced. Newton's Second Law says that once an object is set in motion, its acceleration will depend on two things: force and mass. In fact, this law of motion is often expressed as an equation: **Force equals mass times acceleration** ($F = ma$).

Force and acceleration are proportional to each other—the amount of force is equal to the amount of acceleration. The greater the force exerted on an object, the more it will accelerate. For example, the harder you kick a ball, the farther and faster it will travel.

The opposite is true of mass. The more mass an object has, the less it will accelerate. If you kick a tennis ball and a bowling ball with the same amount of force, the heavy bowling ball is going to move slower and go a shorter distance than the tennis ball. A heavier object requires more force to set it in motion.

Newton's Third Law of Motion

- **For every action, there is a reaction that is equal in magnitude and opposite in direction.**

Forces always occur in pairs, and Newton's Third Law of Motion helps us understand the relationship between pairs of forces. Every time a force, or action, occurs, it causes a reaction. We can describe the reaction in terms of its strength, or magnitude, and also its direction.

The magnitude of the action is equal to the magnitude of the reaction. For example, if you toss a pebble into the water, it's going to create a small ripple or splash. If you hurl a large boulder at the water, the splash is going to be bigger. The force of the action and reaction always match up.

While an action and its reaction are equal in magnitude, they are opposite in direction. The rock plunges down into the water, but the water splashes up. When you throw or shoot something forward, the recoil of the force pushes you backward. Every time a force acts on an object, it causes a reaction force in the opposite direction.

Kinetic & Potential Energy

Energy is the ability to do work. An object doesn't have to be in motion to possess energy. **Potential energy** is energy that's stored in an object. (In fact, it's also referred to as **stored energy**.) An object's position or circumstances give it potential energy. A spring on the bottom of a pogo stick has **potential energy** when someone is standing on the pogo stick. The coil of the spring compresses when pressure is applied, storing up energy that will later be released. The more height and mass an object has, the more gravitational potential energy it has.

Once an object is in motion, it has **kinetic energy**. When the spring compresses and releases, the kinetic energy of the spring pushes the pogo stick and its rider up into the air. When the person jumps on the pogo stick and the spring compresses again, more potential energy is stored in the spring. When the spring releases, the kinetic energy of the spring pushes the rider up once again.

How does this fit into the big picture? The following page comes from a brand-new publication by the National Science Teachers Association entitled, "The NSTA Quick Reference Guide to the NGSS, Elementary School." I highly recommend reading chapter 2: K-12 Progressions. This chapter is free to download off of the NSTA website, or you can download it from my NJ Science Convention Workshop Resources page on my website: www.coolsciencelab.com
Direct link to resources page: www.coolsciencelab.com/Science_Convention_Extras.htm

Disciplinary Core Ideas in Physical Science (*continued*)

	Grades K–2	Grades 3–5	Grades 6–8	Grades 9–12
PS2: Motion and Stability: Forces and Interactions				
PS2.A: Forces and Motion	• Pushes and pulls can have different strengths and directions. (K-PS2-1),(K-PS2-2) • Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. (K-PS2-1),(K-PS2-2)	• Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative, addition of forces are used at this level.) (3-PS2-1) • The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.) (3-PS2-2)	• For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1) • The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2) • All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MSPS2-2)	• Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1) • Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. In any system, total momentum is always conserved. (HS-PS2-2) • If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS-PS2-2),(HS-PS2-3)
PS2.B: Types of Interactions	• When objects touch or collide, they push on one another and can change motion. (K-PS2-1)	• Objects in contact exert forces on each other. (3-PS2-1) • Electric and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (3-PS2-3),(3-PS2-4) • The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center. (5-PS2-1)	• Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3) • Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the Sun. (MS-PS2-4) • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, a magnet, or a ball, respectively). (MS-PS2-5)	• Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4) • Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-4),(HS-PS2-5) • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (HS-PS2-6),(secondary to HS-PS1-1),(secondary to HS-PS1-3)

Name: ______________________________

Forces in Action!

In the table below, write in the distance that the truck travels for each experiment:

With Slope # 1	No Weight	Small Weight	Big Weight
No Parachute			
Small Parachute			
Big Parachute			

With Slope # 2	No Weight	Small Weight	Big Weight
No Parachute			
Small Parachute			
Big Parachute			

In which experiment did the truck go the furthest distance? **Put a smiley face in that box.**

In your best words, explain why that was the ONLY experiment to go the furthest distance: ___________

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Quiz about the Activity…..

- **How could you make a sheet of paper fall as quickly as possible?**

  a. Attach a parachute to it.
  b. Cut it in half.
  c. Crumple it into a ball.

- **When an object falls, air resistance….**

  a. Acts in opposite direction to its weight
  b. Acts in the same direction to its weight
  c. Does not act at all

- **Where would you feel the heaviest?**

  a. The Earth
  b. The Moon
  c. You would feel equally heavy on both.

- **Which of the following is TRUE?**

  a. Gravity only acts through air, not through water or land.
  b. Gravity does not act on airplanes flying in the sky.
  c. Gravity always acts towards the center of the Earth.

- **Which of these is not a force?**

  a. Friction
  b. Weight
  c. Height

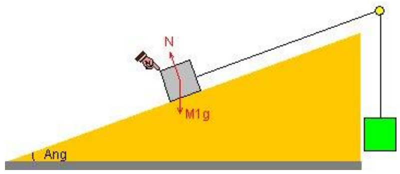
- **Which of these is FALSE?**

  a. A moving object keeps on moving until a force stops it.
  b. A moving object eventually runs out of force and slows down.
  c. A moving object travels in a line until a force changes its direction.

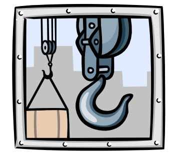
- **When an object is at rest…**

  a. There are no forces acting on it.
  b. There are forces acting on it, but these forces are balanced.
  c. There is just one force acting on it, gravity.

Name: ______________________________



Forces in Action!



In the table below, write in **how many units of force** you needed to move the wooden block for each experiment:

SMOOTH surface:

PREDICTION	Type of Slope	1st TEST	2nd TEST	3rd TEST
	NO Slope			
	One Book			
	Both Books			
	Both Books + The Green Tray			

ROUGH surface:

PREDICTION	Type of Slope	1st TEST	2nd TEST	3rd TEST
	NO Slope			

QUESTIONS…

1. **WHICH EXPERIMENT** required the **MOST** force? Explain why you think so!

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2. **WHICH EXPERIMENT** required the **LEAST** force? Give me at least 2 reasons why you think so!

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CHALLENGE:

In your groups, come up with at least one way in which you can move the wood block on the **ROUGH surface** using <u>NO more than</u> 10 units of force! You MUST start the block COMPLETELY on the area of the sandpaper! **Explain how you were able to do so!**

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www.coolsciencelab.com/Science_Convention_Extras.htm

Listed below, are some website activities and resources that relate to our exploration of balanced and unbalanced forces:

What is a Force? -Even when we ask adults this question, we get some very interesting answers!

What Forces Are Acting on You? -When an object is at rest, the forces are balanced. What does this statement really mean? This video does a fairly good job of explaining this.

How Much Force is 1 Newton? -Although in the earlier grades, we do not get into the mathematical calculations of balanced & unbalanced forces, some of the online resources that I have found, do allow you to see how many Newtons of force you are applying in various simulations. Students will invariably ask, "What exactly is a Newton of force?" This video does a fairly good job of explaining what a Newton of Force really is!

The K-12 Science Progressions! -This download comes from part of the book entitled, "The NSTA Quick Reference Guide to the NGSS, Elementary School." This document gives you a good perspective of where your teaching of science on the elementary level fits into the larger picture

Using Balloons to Show Balanced & Unbalanced Forces -This is a great video from a school system in England done by a couple of first grade students and an eleventh-grade student exploring balanced and unbalanced forces using balloons, paper clips, & a hair dryer.

Forces & Motion Activity Tub -First and foremost, please be sure to read the 2 pages on the basics of forces & motion at the beginning of this great teaching guide. This background information is crucial for any teacher to understand when teaching any grade level student, the basics of motion and forces. Although many of the activities in this particular printable seem to be geared for middle school students, you may very well find activities that could be modified for younger students.

Forces & Movement -In this activity, drag the red handle back to the yellow light to give the truck a little push. Find out how far the truck travels. Be sure to test the larger truck as well. Does it go as far? Why or why not?

Forces in Action -In this activity, see how far the truck travels when you increase or decrease the slope. You can also see how placing different sized parachutes and different sized weights on the back of the truck affects the motion of the truck as well.

Exploring Friction -In this activity, see how far the sleigh travels on different surfaces using either a small push force or a large push force. Which surface did the sleigh travel the furthest? Why do you think so? Which surface did the sleigh travel the smallest distance? Why do you think so?

Forces Interactive -This website allows you to explore virtually everything you'd ever want to know about forces! Click on the RED box or the "mind map" on the bottom of the screen to begin your adventure.

PhET Forces & Motion: Basics -This website does a great job of exploring the concepts of net force, motion, friction, and acceleration. **Click here** to get to the teacher resources for this activity.

PhET Balancing Act -This website does a great job of having students explore balancing and proportional reasoning. **Click here** to get to the teacher resources for this activity.