Motion & Design Unit Overview

"MOTION"
Science Focus: Developing an evidence-based explanatory model

Lesson	Connection to Kit Curriculum	Lesson Title	Suggested Time**
1	**ADDED** NEW LESSON	Pre Unit Assessment: Developing Models to Explain the Skateboarder's Motion YouTube video: https://www.youtube.com/watch?v=2MUlhxkpiTw	45-60 mins
2	**REVISED** KIT LESSON 2	Using Drawings to Build Standard Car	30-45 mins
3a	**SAME** KIT LESSON 3	Pulling a Vehicle: Looking at Force Just-in-Time Instruction*: Balanced & unbalanced forces	45-60 mins
3b	**ADDED** NEW LESSON	Tug-of-War: Looking at Forces Just-in-Time Instruction: Balanced & unbalanced forces	45-60 mins
4	**SAME** KIT LESSON 4	Testing the Motion of Vehicles Carrying a Load Just-in-Time Instruction: Gravity & weight	45-60 mins
5	**ADDED** NEW LESSON	Testing How Varying Pulling Force Affects Motion of Loaded Vehicle (Extension of Lesson 4) Just-in-Time Instruction: Energy & force	45 mins
6	**REVISED** KIT LESSON 8	Evaluating Vehicle Design: Looking at Friction Just-in-Time Instruction: Friction as a stopping force	90-120 mins
7	**SAME** Kit Lesson 6	Looking at Rubber Band Energy Just-in-Time Instruction: Energy and energy transfer/transformation	45 mins
8	**SAME** Kit Lesson 7	Testing the Effects of Rubber Band Energy Just-in-Time Instruction: Energy and energy transfer/transformation	45 mins
9	**ADDED** NEW LESSON	Adding to Models using Evidence from Activities	45 mins
10	**ADDED** NEW LESSON	Writing the Evidence-Based Explanation	60 mins

** "Just-in-time Instruction" topics are content pieces students need to continue reasoning about a phenomenon to explain how and why it happens. These are suggested in each lesson but may need to be supplemented or expanded based on your students' questions and ideas.*
*** Suggested times can span across multiple science class periods. For example a 90 minute suggested time would take two 45-minute class periods.*

"DESIGN" Engineering Focus: Meeting Design Requirements
(Follow Kit Lessons 5 & 9-16)

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Teacher Background: Skateboard Jump

This unit is anchored by a skateboard jump phenomenon containing an successful jump and an epic fail. See video here: https://www.youtube.com/watch?v=2MUlhxkpiTw

To understand this story, students must be able to connect and explain ideas about:

1. **Balanced and unbalanced forces**
   - "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." (NGSS DCI PS2.A Forces and Motion)

2. **Transfers and transformations of energy**
   - "The faster a given object is moving, the more energy it possesses. Energy can be moved from place to place by moving objects or through sound, light, or electric currents." (NGSS DCI PS3.A Definitions of Energy)
   - "Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced" (NGSS PS3.B Conservation of Energy and Energy Transfer)
   - "When objects collide, the contact forces transfer energy so as to change the objects' motions." (NGSS DCI PS3.C Relationship between forces and energy)

3. **Forces affect the motion of objects**
   - "The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center." (NGSS DCI PS2.B Types of Interactions)
   - "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)." (NGSS DCI PS2.A Forces and Motion)
   - "When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object." (NGSS DCI PS3.C Relationship between Energy and Forces)
   - "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." (NGSS DCI PS2.A Forces and Motion)

Featured NGSS Cross-Cutting Concepts:

- Energy and Matter: "Energy can be transferred in various ways and between objects."
- Cause and Effect: "Cause and effect relationships are routinely identified and used to explain change."

Photos of Success

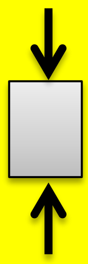
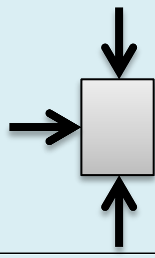
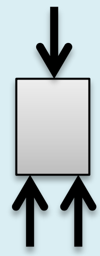
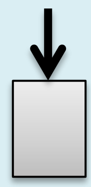
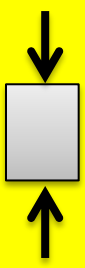
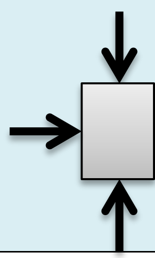
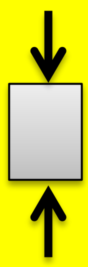
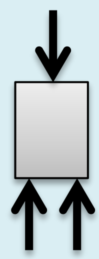
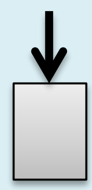
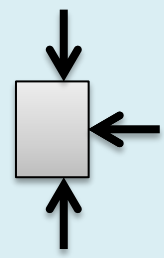
Photos of Epic Fail

Forces story for the skateboarder

1. Standing still. Standing still gravity is acting on him and the force of the ground is holding the boarder up (the force is from ground and it goes through shoes to hold him up—an equal and opposite force).
2. Pushing. Now there is an unbalanced force and acceleration.
3. Coasting. Like in space, he is in motion and stays in motion. There is friction force that slows him down but this is not as important.
4. Jump. The force of the ground is pushing up and the force of his legs pushes him up and he is unbalanced and accelerating upward. There is no force yet to stop him so he continues going forward.
5. Freefall. The earth is no longer pushing the boy up. The only force is the force of gravity pulling him down.
6. Landing. Successful - He lands and there are balanced forces again. He is coasting. The force of friction will eventually slow him down. Epic fail - The front wheels landed on the ground, the back wheels on the speed bump. The front wheel can't roll because his weight is pushing down over that point. This stopping force (can't roll) is applied far lower than his center of gravity, he spun over onto his bottom.

Energy story: In both situations the skateboarder is moving when he enters the frame. A body in motion stays in motion (inertia). He applies a force using chemical energy in his leg muscles to push him forward. Chemical energy is converted into kinetic energy (motion energy). He then pushes himself into the air using more chemical-to-kinetic energy. When he is up in the air he has potential energy, which is then converted into kinetic energy as he falls back down to the ground. In the last frame we hear the boy hit the earth, part of the energy is converted to sound, heat and plastic deformation. Energy is the ability to do work; it is not created or destroyed.

Forces Story with Free body Diagrams

	1. Standing still	2. Pushing	3. Coasting	4. Jumping	5. Free fall	6. Landing
Successful ride	Standing still, at rest- balanced forces 	Pushing- forward/ pushing force applied unbalanced forces 	Coasting velocity stays the same - balanced forces 	Jump- up force applied- unbalanced forces 	Free fall- gravity force pulls boy to the earth - unbalanced forces 	Successful Landing- forces are balanced 
Epic fail	Standing still, at rest- balanced forces 	Pushing- forward/ pushing force applied unbalanced forces 	Coasting velocity stays the same balanced forces 	Jump- up force applied unbalanced forces 	Free fall- gravity force pulls boy to the earth unbalanced forces 	Epic Fail- forces are not balanced 

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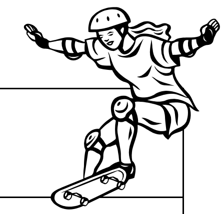
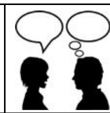
Summary Table

What evidence have we collected so far?



What did we do?	 What did we observe? What patterns did we notice?	 What did we learn from our observations?	How does this help us explain the skateboard jumps?
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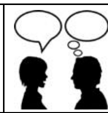
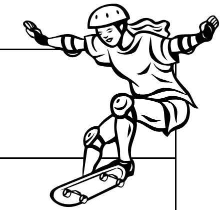
What did we do?	 What did we observe? What patterns did we notice?	 What did we learn from our observations?	How does this help us explain the skateboard jumps? 
4			
5			

Summary Table **TEACHER GUIDE**

This teacher's guide describes the purpose of each activity featured in this unit that helps students explain the skateboarder jump phenomenon (see YouTube video: https://www.youtube.com/watch?v=2MUlhxkpiTw). After each activity students can fill out a row of the summary table. This can be done individually or in small groups and then discuss whole class so students make connections between activities and understand how each activity helps build an explanation of the skateboarder.

What did we do?	 What did we observe? What patterns did we notice?	 What did we learn from our observations?	How does this help us explain the skateboard jumps? 
PULL THE EMPTY CAR Pulling an Empty Vehicle with Washers (KIT LESSON 3)	1. Empty car rolled faster with more washers pulling it. 2. Empty car kept moving even if the washers stopped at the floor. 3. Car crashed into the bookend to stop and made a noise.	We need a force to make a stopped car start moving. Once the car is going, it only stops if something else touches it (bookend).	• The boy pushes on the ground with his foot to start moving. • The boy will only stop if something stops him (either he lands and rolls away or falls hard and ground stops him.) • The boy's body made a noise when it hit the ground just like the car hitting the bookend.
SPEED OF LOADED CARS Pulling a Loaded Vehicle with Washers (KIT LESSON 4)	1. It takes more <u>time</u> for the heaviest loaded car to get moving when all cars are pulled with same force. 2. Car kept moving even if the washers stopped at the floor. 3. The heavy car hit the bookend harder than the empty car.	Takes longer time for heavy things to get moving. Heavy things have more inertia.	The boy has to push and push to get rolling fast enough. It took him some time to get going. His fall hurt because he took way LESS <u>time</u> to stop his load/weight so he felt all the force almost at once.
GETTING GOING How much force does it take to get each vehicle to move? (NOT IN KIT, EXTENSION OF KIT LESSON 4)	1. It takes more <u>force</u> (more washers) to get 2-block load to move than an empty car.	More force is needed to start and stop heavier objects.	If boy was wearing a back pack, his fall would have hurt more because it would take more <u>force</u> to stop him. He would also have to push more (more force) to get moving.
LOOKING AT FRICTION (KIT LESSON 8)	1. Spinning wheels have to touch the axle. If the axle is sticky or crooked, the wheels won't roll as well. 2. Also, we observed that draggin the car on carpet is harder than on the table.	Higher friction between two touching things slows down motion.	If the skateboarder had muddy wheels he couldn't go as fast because the friction of the mud between the axle and wheel would slow down the wheels rolling. When he lands successfully, he would eventually roll to a stop because the friction between the concrete and his wheels would eventually pull him to a stop.
RUBBER BAND CAR (KIT LESSONS 6 & 7)	By increasing twists, the speed of the car increases.	The twisted rubber band stores energy and it only gets used if the rubber band is allowed to untwist.	The skateboarder will move faster if he pushes with his leg muscles harder on the ground. There is energy in his muscles from food that he can use to skateboard. food energy → motion energy

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LESSON 1: Developing Models to Explain the Skateboarder's Motion

Objectives and Overview

This lesson introduces students to ways of observing and talking about force and motion using everyday language by using the "Skateboard Jump" phenomenon (YouTube video: https://www.youtube.com/watch?v=2MUlhxkpiTw). In this lesson students develop their own explanatory models using their current level of understanding to explain why the skateboarder has success on his first jump and falls on the second jump.

- *Students share observations, ideas and questions about "Skateboard Jump"*
- *Students develop initial models to explain how skateboarder motion is caused by forces.*

Next Generation Science Standards (NGSS) (http://nextgenscience.org/)

Disciplinary Core Idea (DCI):

PS2.A Forces and Motion & PS2.B Types of Interactions

- The effect of unbalanced forces on an object results in a change of motion.
- Patterns of motion can be used to predict future motion.
- Some forces act through contact, some forces act even when the objects are not in contact.
- The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center

PS3.A Energy & PS3.B Conservation of Energy and Energy Transfer

- Moving objects contain energy. The faster the object moves, the more energy it has.
- Energy can be moved from place to place by moving objects, or through sound, light, or electrical currents.
- Energy can be converted from one form to another form.

PS3.C Relationship between energy and forces

- When objects collide, contact forces transfer energy so as to change the objects' motions.
- When two objects interact, each one exerts a force on the other, and these forces can transfer energy between them.

Science and Engineering Practices (SEP): Developing models - Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables

Cross-Cutting Concept (CCC): Cause and Effect - Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

Materials

For the class:

- *"Skateboard Jump" video* http://www.youtube.com/watch?v=2MUlhxkpiTw
- *1 Skateboard (Bring from home or borrow a student's)*

For each pair of students:

- *1 model scaffold sheet (11" x 17" with 5 frames/panels per jump)*
- *2 pencils with erasers (colored pencils optional)*
- *1 laminated photo card comparing freeze-frames of each of the skateboard jumps*

Lesson Directions

1. Introduce the motion and design unit by having students pass around and look at a skateboard. (If you're feeling brave, you can stand on the board and roll a bit. Otherwise, hold it up so students can see it.) Explain that over the next few weeks we will be describing motion looking at speed and direction and investigating the causes of different types of motion using a skateboarding video.

2. In order to focus discussions, we will use a video of a skateboarder jumping over a speed bump. *Preface the skateboard video by letting students know to pay attention to what the skateboarder does before, during, and after each jump.* Play the skateboard video and ask students to be prepared to share their observations about what they see happening in both jumps. Allow students to spontaneously talk to one another as they watch. Replay the video if needed.

3. Make a chart on the board to record a few observations from students about each jump. This list will serve as a reference for students when they work on their models.

4. Tell students that they will be working in partners to explain why the skateboarder succeeded the first jump but failed (or as he put it "epic fail") on the second jump. Show the model scaffold page and briefly explain to students that they will focus on 5 main phases of the jump. They can add arrows, lines, words, etc. to express their thinking about the skateboarder's motion and the skateboard's motion.

5. Pass out model scaffold sheets. Students work in pairs to write and draw to develop their model. As students work, walk the room first to address any procedural questions and then again to listen in on what students are talking about. After asking the question, allow several seconds of wait time. Below are some sample questions you can ask while you visit each pair. It helps to start with an observation level question then move towards asking about less observable features such as forces (gravity, friction, pushing) and how force relates to his direction of movement.

OBSERVATION LEVEL:

1. What happens to get the skateboarder moving?
2. How does he move to get the jump to work?
3. How does his "touch-down" look different in both jumps? (Right at the point he makes contact with the ground.)
4. In both jumps, how does the skateboarder come to a complete stop after the jump? (You can't observe this for the "successful jump", but what would you think?)

UNOBSERVABLE (OR LESS OBSERVABLE) LEVEL:

1. How do you think the force of gravity plays into both jumps?
2. When the skater is in the air, he can't really touch anything, so why

does he keep moving forward?

3. In the failed jump, why do you think the skater didn't fall backwards?
4. In the failed jump, the skater landed with his back wheels on the speed bump and front wheels on the ground. Why do you think landing with the back wheel on the speed bump would make a difference compared to landing with all wheels on the ground like he did in the good jump?
5. In the "successful jump", the skateboard continues touching his feet when he's in the air but skateboard isn't strapped on, how come it stays touching during the jump?
6. In the "epic fail" jump, it looks like he's not even touching the skateboard with his feet in frame 3. Why do you think the skateboard keeps moving forward and doesn't just fall down right away?

"WHAT IF" SCENARIOS

1. How do you think both cases would be different if the skater were going really, really fast before he tried the jump?
2. What if it were raining and the ground was wet? How do you think having a wet surface would affect his skateboarding jumps?
3. Let's say the skateboarder has a ton of homework and is wearing a back pack full of books. How might he have to change his movement to do a successful jump?

7. Name or call on specific pairs to describe their hypotheses or ideas about why the skateboarder was successful on the first jump but then had an 'epic fail'. Record a list of hypotheses students have identified as being important on chart or butcher paper. This list should be revised as students gather evidence (it is a 'rough draft' that will be revised over time. It can be messy with cross-outs, add ons, etc.)

8. End the lesson by explaining to students that they will be doing several investigations to gather evidence for some of their ideas about the skateboarder's motion.

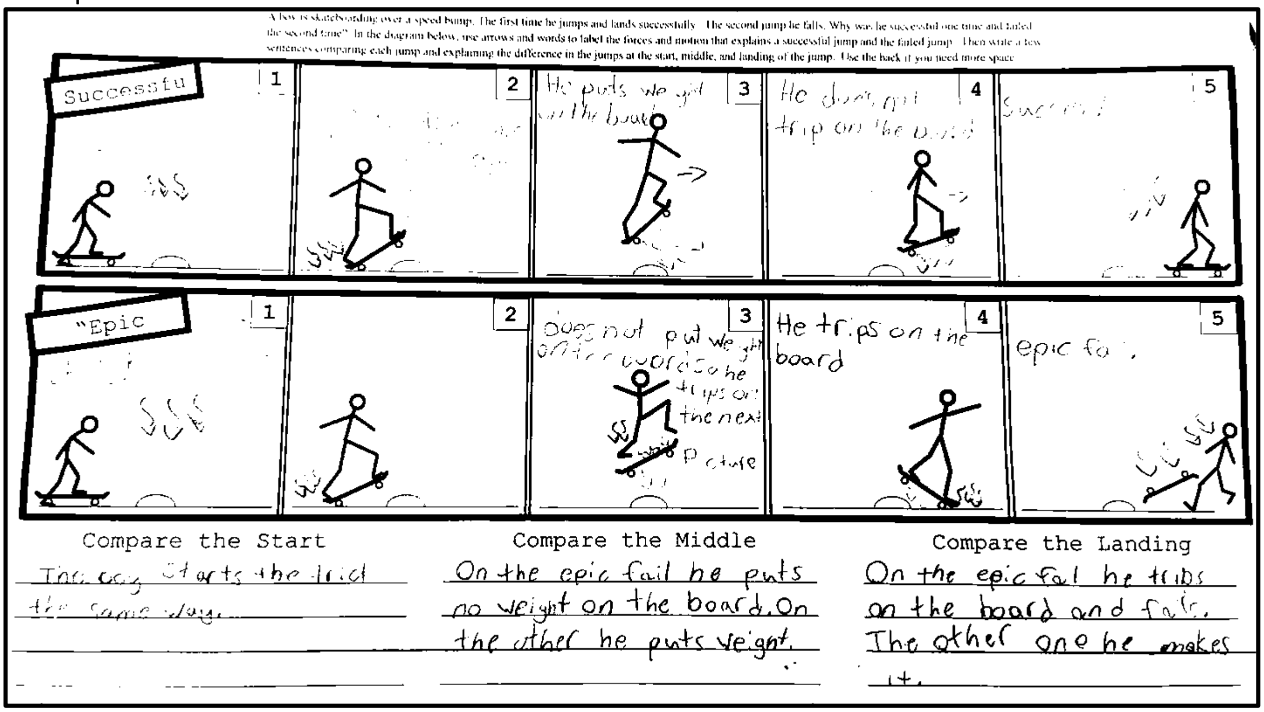
Planning for future instruction

As you listen in on student talk and examine students' work on developing their models, look for partial understanding about big science concepts such as transfer of energy, how speed affects motion, how objects get moving, stay moving, and stop, any ideas about balanced and unbalanced forces. Also, students may or may not use any scientific terminology; let them explain their ideas using their own words. There is time later in the unit to map on the "science term" to the student's way of saying it.

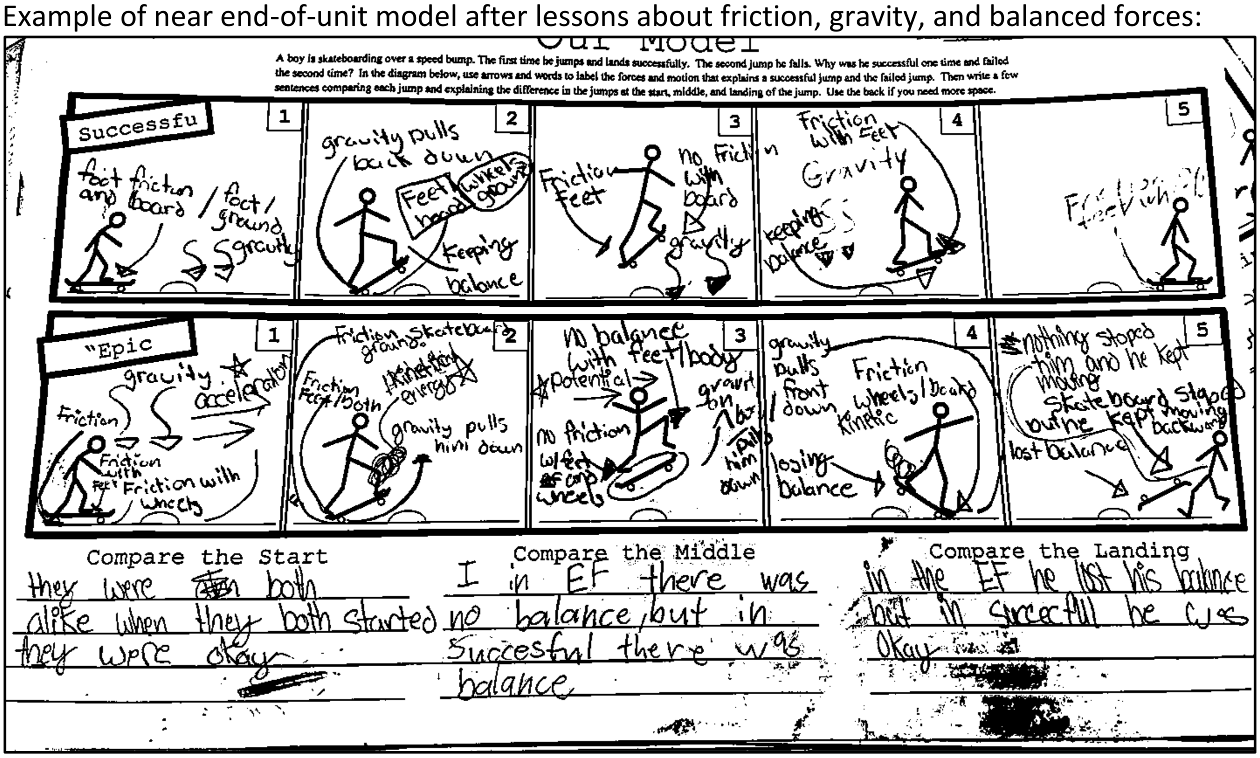
Use ideas students have expressed to help tailor future lessons. For example, if students aren't initially attending to energy transformations, keep that in mind when you engage students with the rubber band car activities. Make sure to spend extra time on having students talk about the energy story in how it starts, rolls and stops with the rubber band cars.

These two examples show how students may begin the unit by expressing more observable things in their model and when nearing the end of the unit students attend to the unobservable factors such as gravity, friction, and center of gravity to explain the skateboard jumps.

Example of initial student model from lesson 1:



Example of near end-of-unit model after lessons about friction, gravity, and balanced forces:

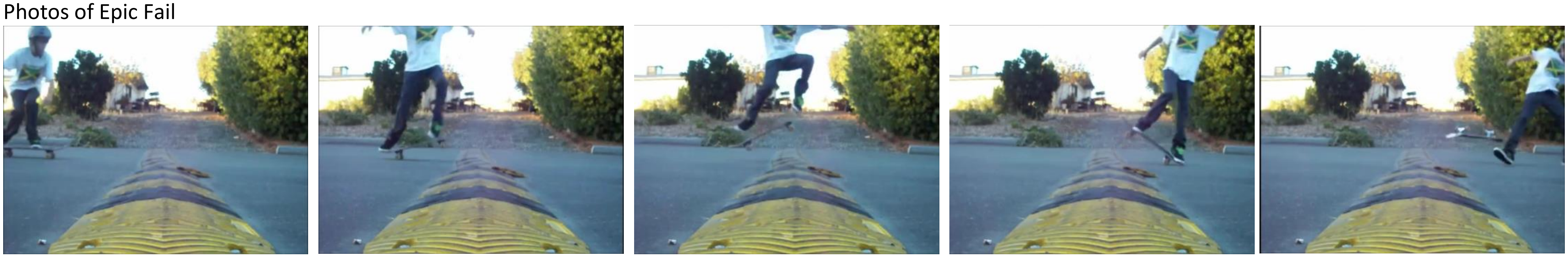


Photos of Success

Photos of Epic Fail

Photos of Success

Photos of Epic Fail



Name: ______________________________

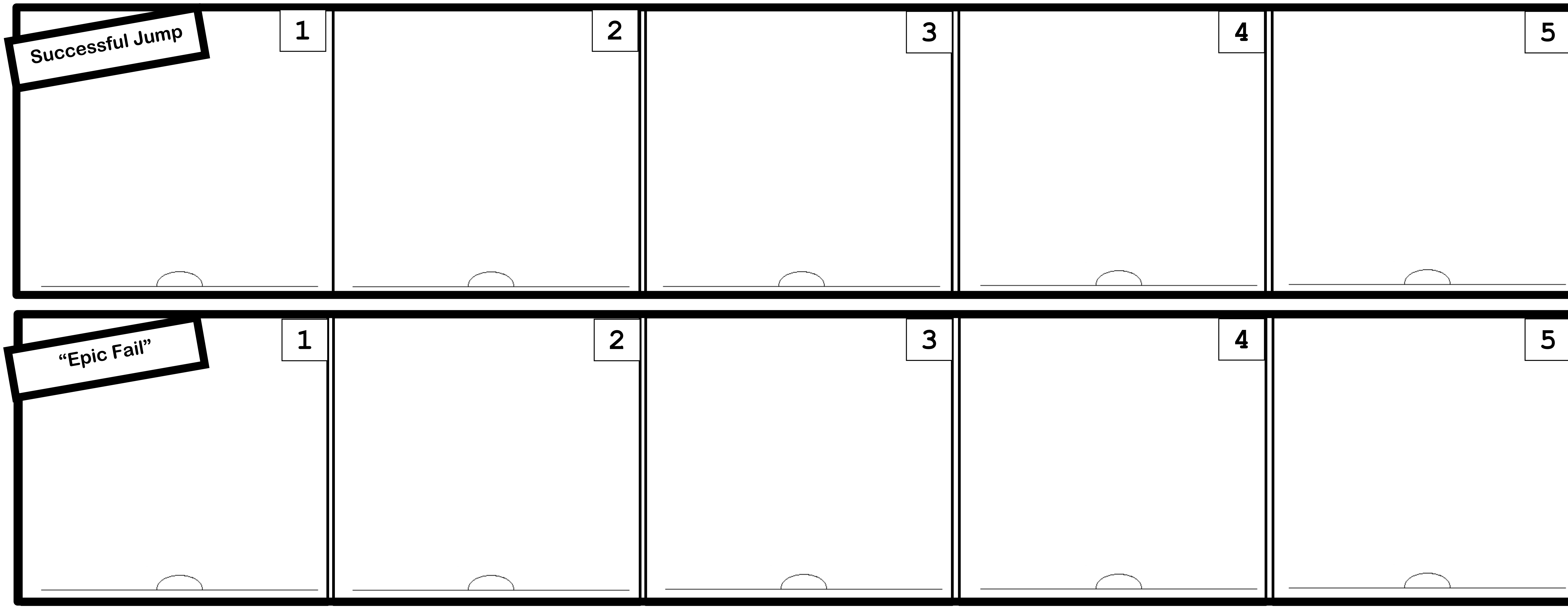
Name: ______________________________

Success vs. Epic Fail: Our Model

Teacher: ______________________________

Date: ______________________________

A boy is skateboarding over a speed bump. The first time he jumps and lands successfully. The second jump he falls. Why was he successful one time and failed the second time? In the diagram below, use arrows and words to label the forces and motion that explains a successful jump and the failed jump. Then write a few sentences comparing each jump and explaining the difference in the jumps at the start, middle, and landing of the jump. Use the back if you need more space.



Success vs Fail: Compare the Start

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Success vs Fail: Compare the Middle

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Success vs Fail: Compare the Landing

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Name: ______________________________

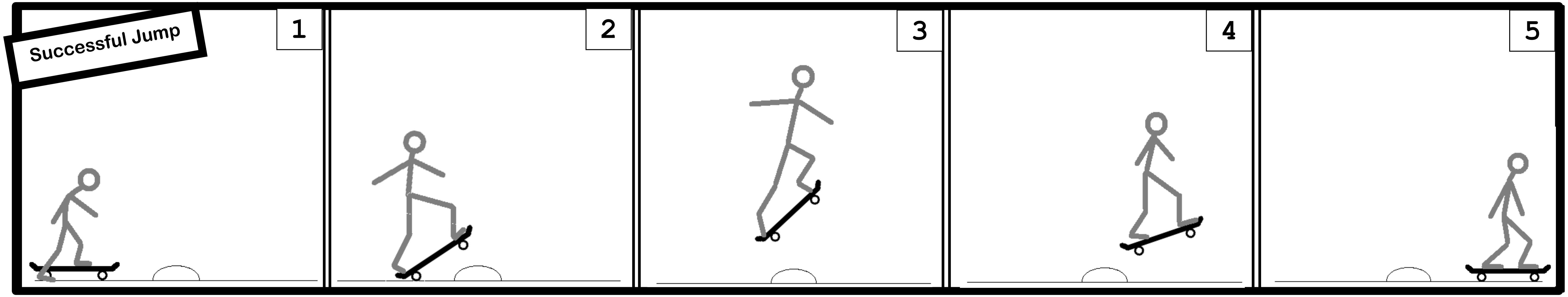
Name: ______________________________

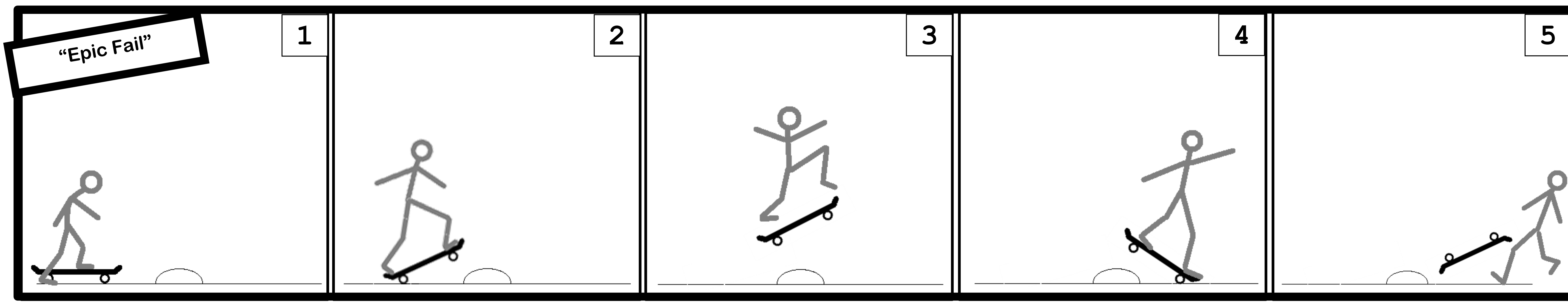
Success vs. Epic Fail: Our Model

Teacher: ______________________________

Date: ______________________________

A boy is skateboarding over a speed bump. The first time he jumps and lands successfully. The second jump he falls. Why was he successful one time and failed the second time? In the diagram below, use arrows and words to label the forces and motion that explains a successful jump and the failed jump. Then write a few sentences comparing each jump and explaining the difference in the jumps at the start, middle, and landing of the jump. Use the back if you need more space.





Compare the Start

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Compare the Middle

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Compare the Landing

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LESSON 2: Developing Models to Explain the Skateboarder's Motion

Objectives and Overview

By the end of the lesson, each table group assemble a standard car which they will use throughout the unit as a test vehicle to observe forces and motion.

- Students build a vehicle by following a two-view technical drawing.
- Students compare vehicles and suggest possible improvements.

Next Generation Science Standards (NGSS)

Disciplinary Core Idea (DCI):

- **PS2.B Types of Interactions.** Objects in contact exert forces on each other (friction, elastic pushes and pulls). [Note: This lesson does not explicitly focus on a core idea. This lesson sets up students for more deeply understanding multiple DCIs in future activities by using this standard car model. While building, students may notice friction or sticking between parts as they build and students can talk about how parts work together when assembled correctly.]

Science and Engineering Practice (SEP):

- **Obtaining, evaluating, and communicating information.** Read and comprehend grade appropriate media to summarize and obtain technical ideas

Cross-Cutting Concept (CCC):

- **Structure and function.** The way in which an object is shaped and its substructure determine many of its properties and functions

Materials *(See curriculum guide for lesson "Using Drawings to Build a Standard Car")*

Lesson

1. **Introduction**: Open the lesson by revisiting the skateboard jump video from Lesson 1 (YouTube: https://www.youtube.com/watch?v=2MUlhxkpiTw). Explain to students that for this unit they will be using a standard car made from plastic pieces as a way to explain the story behind the successful and unsuccessful skateboard jumps.

2. **Construct the car:**
    a. Instead of spending time on having students draw during this lesson as suggested in the curriculum guide, allow students time to construct the standard car using the technical drawing provided. (Note: This is a good time to revisit classroom norms about sharing and turn taking especially since each table group will be assembling one standard car.)
    b. Each group needs one standard car that they will be used in future activities as a test vehicle to learn about forces and motion. Have a place in a classroom cabinet, on a windowsill, or table where each group can store their car.

3. **Looking at car design**:

a. After students complete their standard vehicles have students look to see if all vehicles are the same. Ask students to explain why all vehicles might look the same (or if one looks different how/why that might have happened).
b. Students may want to improve the design of their cars by adding small pieces so that the car stays together better (ex: Sometimes the wheels are loose or fall off unless they add a small clip piece).

4. **Closing**: Explain that they will use this car throughout the next few lessons to do different tests so we can better understand and gather evidence to explain the skateboard jump. Option: Discuss how the standard car and skateboard are similar and different.

(See guide pgs 15-20 for lesson "Using Drawings to Build a Standard Car" for more details.)

LESSON 3a: Pulling a Vehicle Looking at Force

Objectives and Overview

In this lesson students will begin learning about balanced and unbalanced forces and how forces cause changes in motion by setting up a system to pull the vehicles they built in lesson 2.

- Students compare and discuss how the motion of their vehicles changes when more or less weight on a string (washers) is used to pull them.
- Students learn that forces cause changes in motion.

Next Generation Science Standards (NGSS)

Disciplinary Core Idea (DCI):

- **PS2.A Forces and Motion** - The effect of unbalanced forces on an object results in a change of motion.

Science and Engineering Practice (SEP):

- **Using Models** - Develop a model using an analogy, example, or abstract representation to describe a scientific principle

Cross-Cutting Concept (CCC):

- **Cause and Effect** - Students identify causal relationships and use these relationships to explain change

Materials *(See kit curriculum guide pgs 25-33)*

- YouTube video links on page 2 of this lesson guide
- Students science notebooks
- Recording sheet 3-A per student (pg 33 of kit curriculum guide)

Lesson *(See kit curriculum guide pgs 25-33.)*

1. **Introduction**: Show students the cart-string-bookend set-up with a demonstration table. Explain that today our focus question is: **How does changing the force affect the motion of the car?**

2. **Setting up the activity**:
   a. Introduce the term **variable.** Tell students that a manipulated variable is a condition that we change or manipulate in an experiment. We can't control the outcome or results of what happens – we measure that. But we can decide the conditions we want to test – these are called manipulated or independent variables. In today's activity, we are manipulating or changing the number of washers (see data table on recording sheet 3-A pg 33).
   b. Pass out recording sheets and have small groups get set up with their materials.

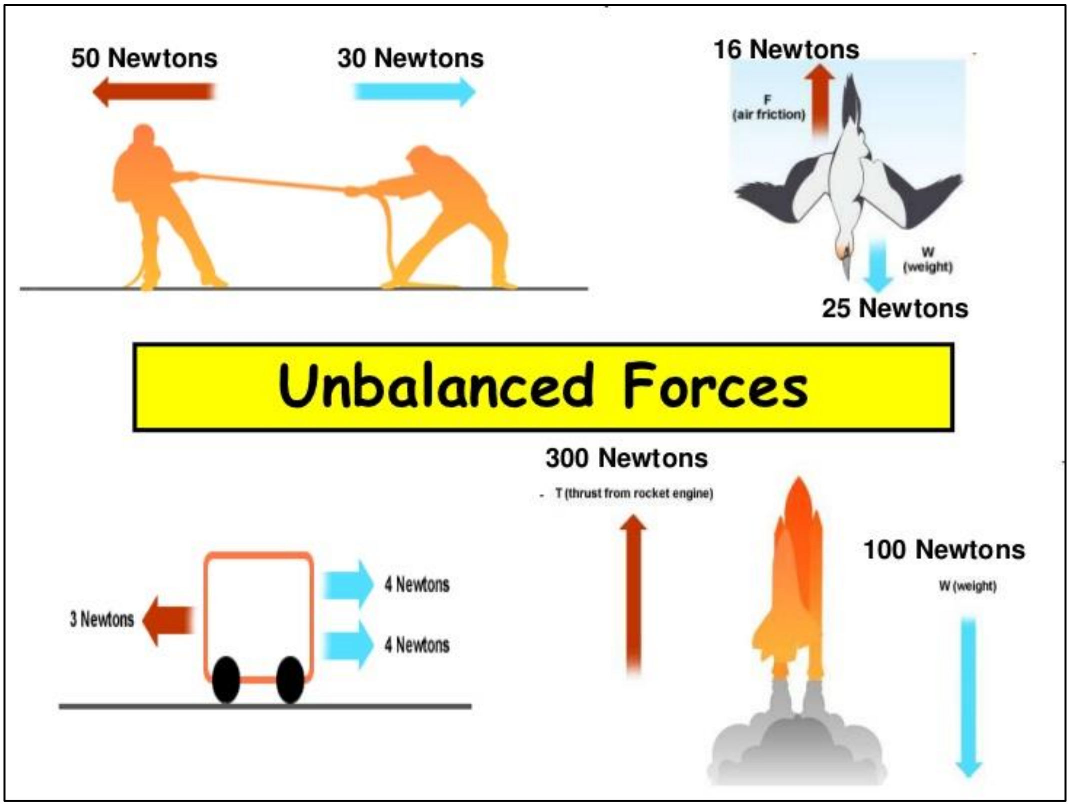
3. **Collect data**: Students use recording sheet 3-A to record their results and rank the speed of the cars motion 1-5.

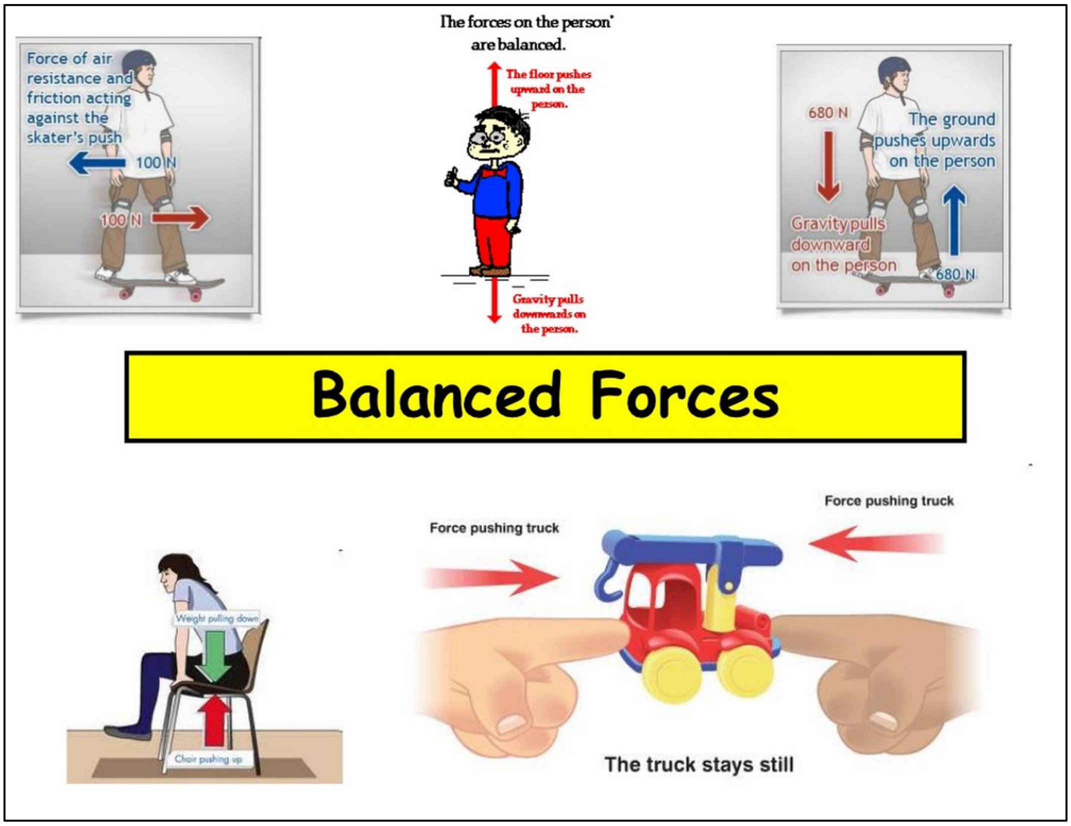
4. **Interpreting results**: Gather students with their recording sheets and ask them what patterns or trends they see in the data to help answer the focus question: How does changing the force (washers) affect the motion (speed) of the car? Think-Pair-Share and then share out focusing on the idea that the more pulling force (more washers) the faster the car moves and the harder it hits the bookend.

~~~ If you need to divide this lesson, pause here and resume next class period. ~~~~

5. **Just-in-time Instruction: Balanced and unbalanced forces**

   a. Explain to students that a force is a push or a pull. Forces affect the motion of objects. Forces can make objects start moving, stay moving, slow down, stop, or stay at rest (motionless). Add a definition to a list of science terms for the unit.

Science Terms: Motion Unit
Force – a push or pull

   b. Tell students that forces can be balanced or unbalanced. Watch this video clip to give students a little information about these descriptions of forces.
      a. BBC Bitesize Forces KS3 (play only from 2:47 – 4:18) https://www.youtube.com/watch?v=9kMNtZvYmqQ
      b. Balanced and Unbalanced Forces posted by the Fuse School (2 min 34 sec) https://www.youtube.com/watch?v=YyJSlcIbd-s

   c. Use page 4 of this lesson guide under the document camera as a pictoral guide for explaining balanced and unbalanced forces using the force pair arrows.

- We can't see forces but we can feel them or see their effects.
- Forces come in pairs and are represented by opposite arrows.
- The size of the arrow is how we show how strong the force is and can show if the pair of forces are balanced or not.

   d. Add to the definition of forces based on the video. It may be slightly different from the example shown at right.

   e. Have students sketch the force pair arrows for their standard car in the activity they just completed. Students can draw the arrow showing the force from the washers and also the arrow in the opposite direction from friction. They may also draw the pair of vertical arrows to show gravity and the normal or reaction force.

Science Terms: Motion Unit
Force – a push or pull — causes changes in motion — can be balanced or not — shown with pairs of arrows
~~~

6. **Summarizing our learning**: Fill in a summary table row for this activity. Have students answer the questions in pairs and share out to fill out each box for observations, learning, and connections.

Activity	Observations	Learning	Connection to Skateboarder
Pulling a Vehicle Looking at Force	Using 16 small washers pulled the empty car faster than 4 small washers. The car didn't move at all with 1 small washer pulling it.	Objects move if one force is bigger than its opposite force. 4 small washers was a big enough force to get the car moving but 2 was not enough to overcome its weight or friction.	**Balanced forces**: Skateboarder was balanced just standing on the board (gravity $\Downarrow$ and reaction force of board $\Uparrow$) **Unbalanced forces**: He started to move when he pushed with his foot $\Rightarrow$ but then his weight and friction from wheels was pushing back $\Leftarrow$ but not as much so he moved forward.





From http://www.slideshare.net/Qwizdom/forces-presentation-7296791

LESSON 3b: Tug of War

Objectives and Overview

In this lesson students will begin learning about balanced and unbalanced forces and how forces cause changes in motion by observing and engaging in a tug-of-war example.

- Students compare and discuss how the motion of each team changes when more or less force (number of and strength of people) is used to pull them.
- Students learn that forces cause changes in motion.

Next Generation Science Standards (NGSS)

Disciplinary Core Idea (DCI):

- **PS2.A Forces and Motion** - The effect of unbalanced forces on an object results in a change of motion.

Science and Engineering Practice (SEP):

- **Using Models** - Develop a model using an analogy, example, or abstract representation to describe a scientific principle

Cross-Cutting Concept (CCC):

- **Cause and Effect** - Students identify causal relationships and use these relationships to explain change

Materials

For the class:

- Tug-of-war rope with bandana or tape marking the middle of the rope
- Meter sticks (1-2)
- Measuring tape(s) (from kit)
- Internet links from this lesson guide queued up

For students:

- Students science notebooks
- Data recording sheet from this lesson guide
- Hard writing surface (for filling out data sheet in the field)
- Exit ticket from this lesson guide

Lesson *(This lesson is added so there are not any corresponding kit curriculum pages.)*

1. Introduction
   a. Explain that today, students will continue learning about balanced and unbalanced forces. Review a definition of force from lesson 3a. (Force = a push or a pull) Show students the video of the skateboarder again. (http://www.youtube.com/watch?v=2MUlhxkpiTw) Ask students to think privately about this question: ***When does the skateboarder lose his balance? Why do you think that happens?*** Turn and share with your partner. (This is a continuation of the summary table discussion from lesson 3a and the connection to the skateboarder. Students may not have been able to articulate the connection yet and this lesson 3b will help with that.)

2. **Engaging in a Tug-of-War**
    a. Setting up for the activity:
        i. Show the pictures of "Game of Tug-of-War 1" and "Game of Tug-of-War 2" in this lesson file. Turn and talk, "What are the differences between the two pictures? Can you predict if the outcome of the games will be the same or different?"
        ii. Explain that in a game of tug-of-war, the middle of the rope is over a mark on the ground. (You can use a yard stick or similar object to mark the ground.) When the tug-of-war ends, the distance of the middle of the rope from the mark on the ground is measured using a measuring tape from the kit. For our purpose, we will count to 5 out loud in unison, and then the tug-of-war round is over.
        iii. Prepare to go outside. Students can go out in pairs. Each pair needs a recording sheet on a hard surface (clipboard or whiteboard) and a pencil. Some students will be in the tug-of-war rounds, so their partner can record the data. (If both partners are in a round, they can get the data later in class.)
    b. Collect data:
        i. Go to the tug-of-war location. Restate safety rules, including: Do NOT wrap the rope around your arm or hands - this can severely injure you.
        ii. Choose 4 students to stand 2 at each end of the rope.
        iii. Make sure the middle is over the mark on the ground. Everyone else should be ready to record. Say "Ready, Set, Pull". Count to 5 in unison. Say "Stop!" Tuggers stop. Have a recorder measure the distance in centimeters (or meters). Record. Repeat.
        iv. Make sure everyone has recorded two measurements.
        v. Change to next grouping as indicated on recording sheet.
        vi. Repeat steps iii-iv. When the recording sheet is full, collect equipment and return to class.

3. **Analyze and Interpret data:**
    a. Share measurements as a class – everyone should have the same measurements since data was collected as a class. In pairs, look at the data sheets and discuss: What trends do you see? How can you explain the results we got for each tug-of-war game? What trends did you notice? (*Students may observe that when there are the same amount of people on both sides, there will be minimal movement due to the balanced forces on each side. When there are different amounts of people on each side, they will observe movement toward the side with less people (unbalanced forces).)*
    b. Have students think-pair-share about the back-pocket questions in the gray box below, in particular answering the lesson's focus question.

c. Revisit the video clips from lesson 3a about balanced and unbalanced forces if needed. Try this computer demonstration after this lesson or before next lesson or as time allows. https://phet.colorado.edu/sims/html/forces-and-motion-basics/latest/forces-and-motion-basics_en.html Choose "Net Forces". Allow your students to try it during their computer time.

QUESTIONS

* Do all of us pull with the exact same force?

* How do we know when one side pulled with more force than the other? What happened?

* How do we know when each side pulled with equal force? What happened?

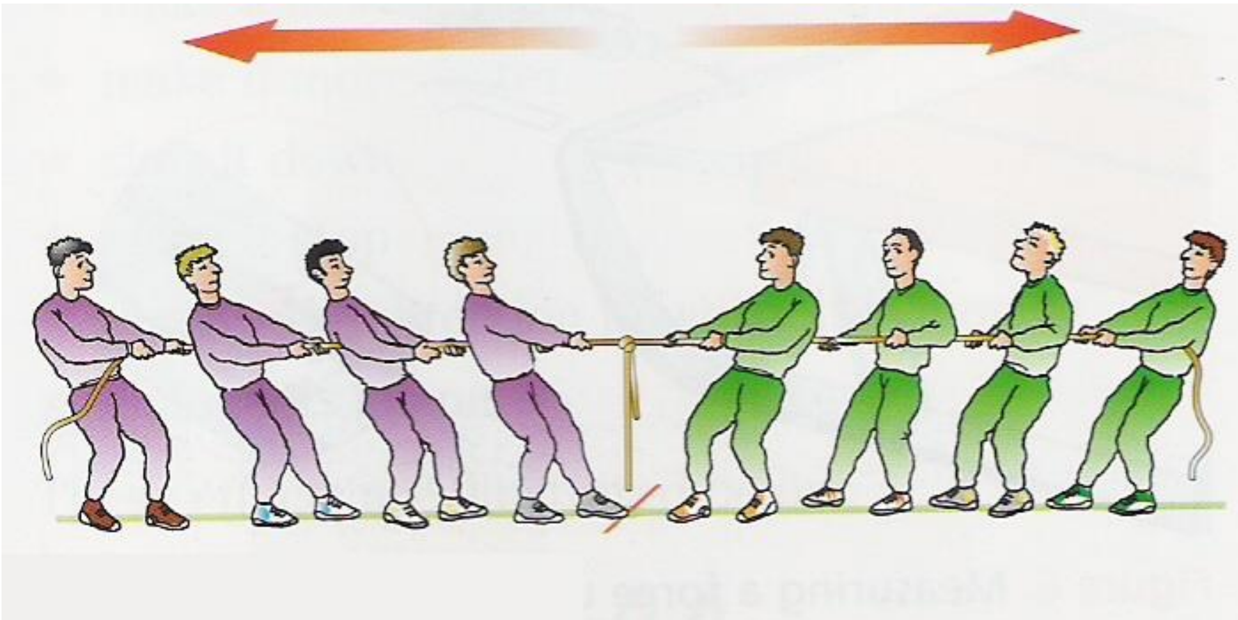
* What happens to something when it is acted on by unbalanced forces?

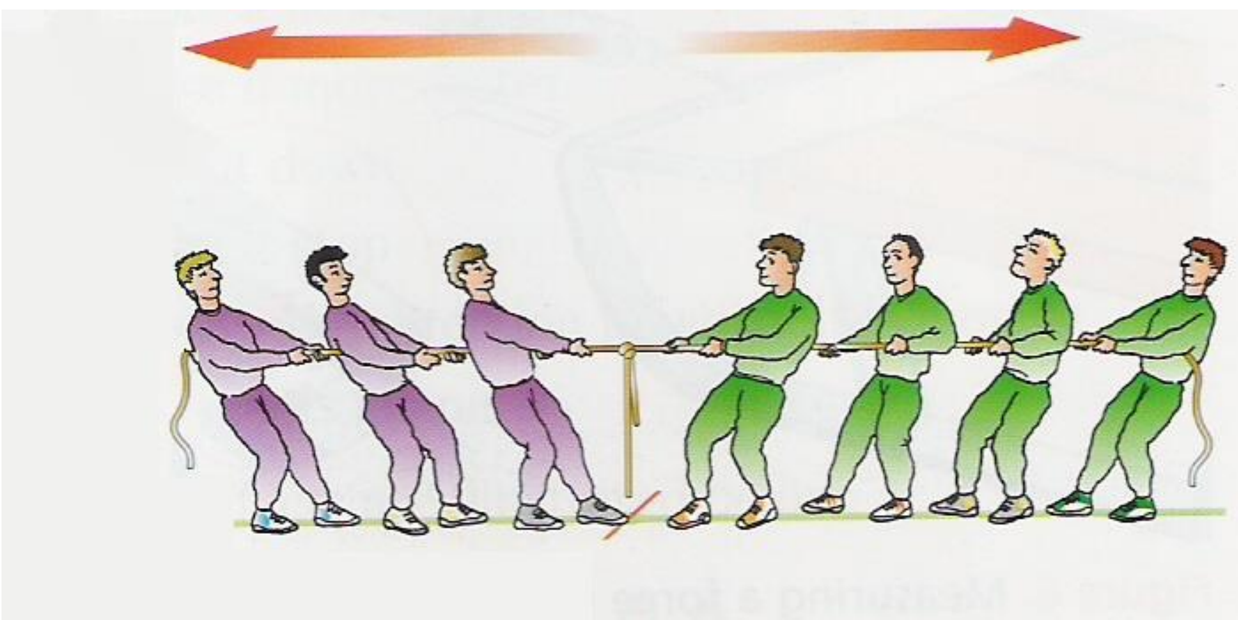
4. **Summarizing our learning**: Fill in a summary table row for this activity. Have students answer the questions in pairs and share out to fill out each box for observations, learning, and connections.

Activity	Observations	Learning	Connection to Skateboarder
Tug of War	Uneven teams had the biggest gain (hardest pull). Even teams sometimes had a tie game or barely won	When forces are balanced on both sides of the tug-of-war rope, it barely moved or stayed almost still even though we were pulling. When forces were not equal then there was motion and one team was pulled toward the middle	The skateboarder must have had some extra force that made him move forward too fast or land so that the forces were not equal causing him to fall forward like in the tug-of-war.

5. Exit task: Have students think about this question: ***With your observations of balanced and unbalanced forces, what can you now say about the skateboarder and his "epic fail"?*** As time allows, students can share their thinking with their partners before turning it in. It can also serve as an entry task or homework.

Diagrams of Tug-of-War



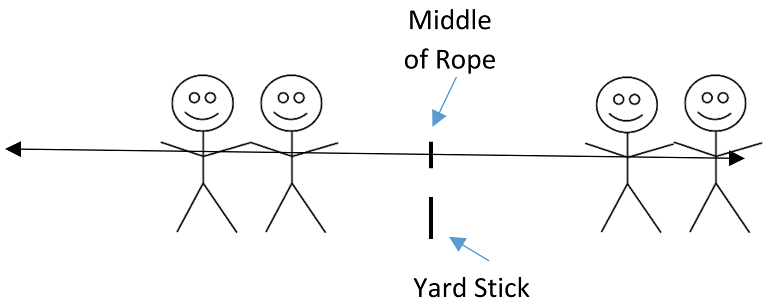


Recording Sheet: Tug-of War

In each trial, the middle of the rope will start in the middle of the yard stick or tape measure. As teams begin to pull the middle of the rope will move. Draw the ending point of the rope and record how far the middle of the rope moved.

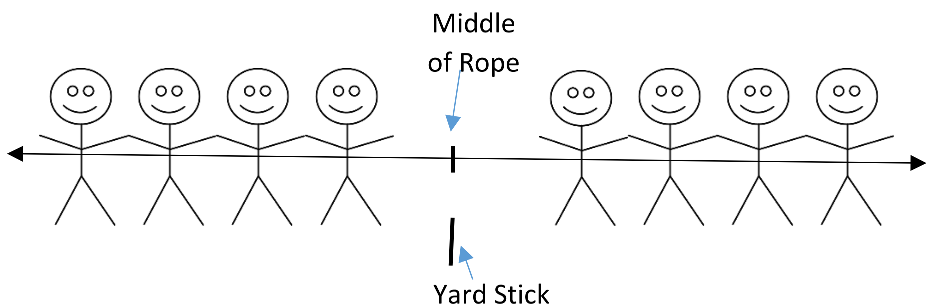
Distance of middle from yardstick

(m or cm)



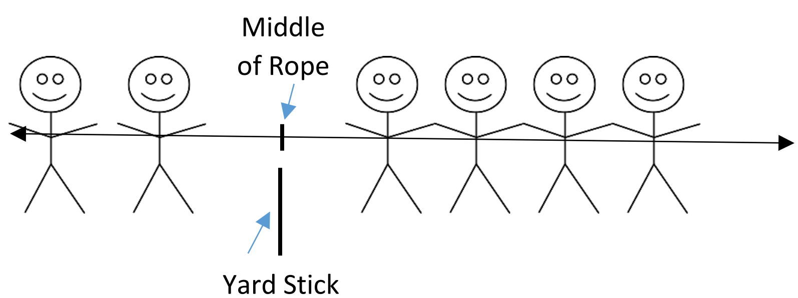
Round 1- ________

Round 2-________



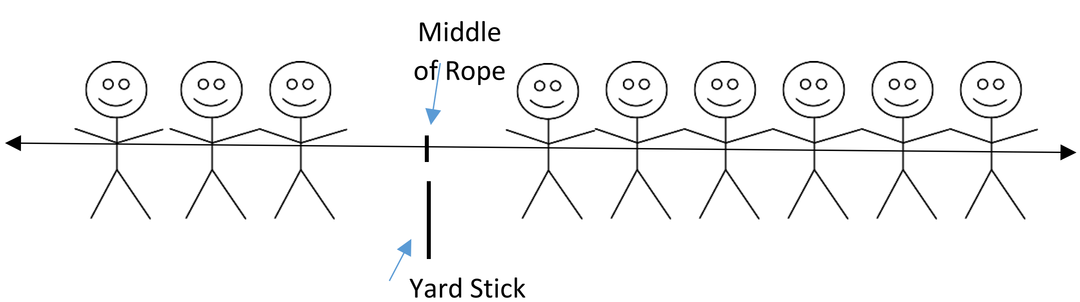
Round 1- ________

Round 2-________



Round 1-________

Round 2-________



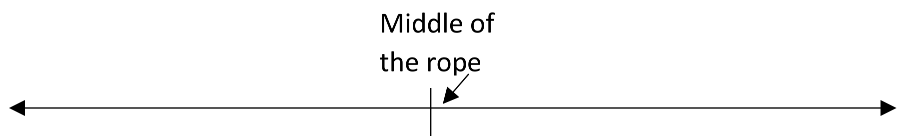
Round 1-________

Round 2-________

Exit Task

With your observations of balanced and unbalanced forces, what can you now say about the skateboarder and his “epic fail”? (Draw and explain your thinking)

Tug of War: Unbalanced Forces



Epic Skateboard Fail: Unbalanced Forces

LESSON 4: Testing the Motion of Vehicles Carrying a Load

Objectives and Overview

Students will build on what they learned in lesson 3 about how to get a vehicle to start moving, keep moving, and stop moving using their standard car design. In this lesson they will vary the weight of the car also to see what strength of force must be used to overcome the force of this weight. They will apply their observations and learning to explain part of the skateboard jump phenomenon.

- Students observe, compare, and discuss how the motion of their vehicles change when their car has heavier or lighter loads.
- Students will measure, compare, and graph results of the elapsed time of travel of their standard car under 3 different weight conditions.

Next Generation Science Standards (NGSS)

Disciplinary Core Idea (DCI):

- **PS2.A Forces and Motion & PS2.B Types of Interactions** – Some forces act through contact, some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.

Science and Engineering Practice (SEP):

- **Analyze and Interpret Data** - Analyze and interpret data to provide evidence for phenomena

Cross-Cutting Concept (CCC):

- **Patterns** - students use patterns to identify cause and effect relationships, and use graphs and charts to identify patterns in data.

Materials *(See curriculum pgs 35-45)*

Lesson Directions *(For more details, see curriculum pgs 35-45)*

1. **Introduction**: Introduce today's focus question by comparing it to what we know about how the skateboarder got moving, kept moving, and stopped: **How much time does it take for different loads to move when pulled with the same force?**
    a. Think-Pair-Share – Show students an empty standard car and a standard car holding 2 blocks. Ask: *How do you think the motion of this empty car and this 2-block car might be different if they are pulled with the same force?* Give students time to think, share in pairs, and share out a few ideas about how increasing the **load** or weight of the car might affect its motion.

2. **Prepare for the activity**:
    a. Review the term **variable** from lesson 3 and explain that today we are keeping the force variable the same (i.e. same number of washers) and changing the load variable (i.e. empty, 1-block, 2-block).

   b. Pass out timers. Have students practice using the timers which they will use to measure how long the car is in motion under different conditions. Be sure they know how to start, stop, and clear measurements on the timers.

3. **Collect data:** Have students work in small groups to collect data on 3 load conditions (empty car, 1-block car, and 2-block car) only using the pulling force of 16 washers. They can use qualitative descriptions like slow, faster, fastest along with their timed data (in seconds) using the stopwatches. Record data in science notebooks.

4. **Create a graph**: On butcher or chart paper, create a class graph (see page 37 in curriculum guide) to show how the 3 different loads related to the time of the journey. Have students use red marker to make an X for their empty car, blue marker for 1-block, and green marker for 2-block. Each group marks their 2-3 trials per condition on the class graph. (Data should show that the heaviest load took the longest time.)

~~~~ You may need to divide this lesson because of time. This is a good stopping point after groups have collected their data and marked it on the class graph. ~~~~

5. **Interpret the graph**: Have students take some silent time to look at the graph and make some observations. Students can write conclusions using data points from the graph about the relationship between load/weight and trip time.
   a. Observation questions: What do you notice? Which loads took longest? Shortest?
   b. Interpretation questions: What is the relationship between the load of the vehicle and the time it took for that car to travel?
   c. Write a conclusion: Use the sentence starters below to write a conclusion from this activity. (If you split this lesson into two time periods, this makes a good entry task or warm-up.)
      The graph shows…(use data points)
      Based on this data, I conclude that…. (describe pattern between load and time)

6. **Just-in-time instruction: Gravity and weight**
   a. Prepare to teach a short instructional segment about gravity and weight by previewing the video(s) below and considering your own understanding of gravity and weight and how it relates to the skateboard jump phenomenon and other motion phenomenon in everyday life (ex: loaded shopping cart vs empty cart).
   b. Write and draw on the board as needed when using the resources below to describe gravity and weight – these are key ideas for this lesson. This could also become a small poster on the science bulletin board for student reference.
      i. Weight is the amount of force gravity exerts on an object. Weight will vary by planet since the planets are all different sizes and have different gravities.
      ii. Gravity is a pulling force that exists between two objects, like a planet and a human body.
~~~~

iii. Watch video clip below and add to a class definition of the terms 'weight' and 'gravity' These can remain posted in the classroom for reference.

c. Supplement this content delivery using video clips. Keep them short and give students time to watch, think, ask questions, and talk to their peers about this science content about gravity. This clip also connects to big unit ideas about balanced (not moving) and unbalanced forces (motion).

Gravity & Force (from phoenixfilmandvideo 1 min 47 sec)
https://www.youtube.com/watch?v=LEs9J2IQIZY

Optional: Students read the short gravity reading at the end of this lesson. Students can tape this into their science notebooks or folders for future reference.

d. Ask students about this activity/data in light of gravity and weight. Using what we have just learned about gravity…
   i. How do you think the Earth's gravity affects each car load condition (empty, 1-block, 2-block) differently?
   ii. Why do you think the heavy car moves more slowly (or takes longer to get started) and the empty car moves fastest? How does gravity help explain this difference?

Science Content Note: Students may bring in other terms or concepts such as momentum, inertia, and friction to explain their ideas – they may or may not use these terms explicitly. You may decide to spend more time to help your students think more about these ideas now by doing an additional "just-in-time" instruction on a topic your students are thinking and talking about. Here is some information to help you:

- **Inertia** - From http://quatr.us/physics/space/inertia.htm: "A law of physics states that "an object at rest tends to remain at rest, and an object in motion tends to remain in motion." Scientists call these tendencies inertia. **Inertia** is a way of measuring how hard it is to change the momentum of an object, whether that's getting it to speed up or getting it to slow down. That depends on how much mass the object has. Big heavy things (things with a lot of mass) have more inertia than light things. You have to push a bus harder than a scooter to get it to move. If something has a lot of mass, it's also hard to get it to stop moving. If the bus was moving fast, you'd need good brakes to get it to stop. Because the bus has more mass than the scooter, it would be a lot harder to stop the bus. That's also inertia - inertia's a way of measuring how hard it is to get something to stop moving, too."

- **Momentum** – From http://quatr.us/physics/space/momentum.htm: "Momentum describes how strong a moving thing is. Things that aren't moving have no momentum. Moving things have less momentum if they are light or moving slowly, and more momentum if they are heavy or moving fast. On Earth, friction with the ground or the air will gradually push an object and make it stop. One way to think of momentum is that momentum measures how hard it will be to stop a moving object. An object has more momentum if it is bigger, or if it is going faster. So if a car (something with a lot of mass) is rolling down the street towards you, it's hard to stop it even if it is going pretty slowly. Or, if someone hits a baseball at you, it's hard to stop it even though it is pretty small, because it is going so fast. But a car going fast will be even harder to stop - then the car will have both a big mass and a fast speed. That's why it's dangerous to walk on train tracks - a train is big and goes fast, and so it takes a long time to stop one. The driver can't just stop the train as soon as he or she sees you."

7. **Summarizing our learning**: Fill out the summary table row and discuss the what-if scenario(s) below. This may take additional time depending on how long a discussion you wish students to have about the activity and the connection to the skateboarder.

"What if" Scenarios to apply to the skateboarder:

What if the skateboarder were carrying a heavy backpack full of homework and textbooks? How is that like the 2-block car? How would having a heavier load affect how much time it takes to get going? To stop?

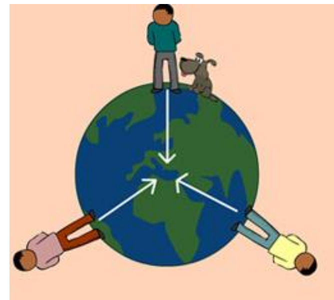
Compare the skateboarding boy to a popular football player (several hundred pounds). How might the motion or forces be different to get them moving, keep them moving, and stop them?

Possible Summary Table Entry

What Did we DO?	Observations	Learning	So What?
Speed of Loaded Cars	It takes more time for the heaviest loaded car to get moving when all cars are pulled with the same force. Car kept moving even if the washers stopped at the floor. The heavy car hit the bookend harder than the empty car.	Takes longer time for heavy things to get moving. Gravity pulls down on all cars but because the 2-block car has more mass (more stuff) it also weighs more and is harder to get started and to stop	The boy has to push to get the board rolling fast enough. It takes him some time to get going because his weight is pressing on the board. His fall likely hurt because he took way less time to stop his load/weight than he did when he landed and rolled away so he felt all the force almost at once when he fell.

A short reading about GRAVITY

Gravity is important to our everyday lives. Without gravity we would fly right off Earth. If you kicked a ball, it would fly off forever and never return to Earth.



Gravity is a pulling force that makes everything fall towards the Earth. The amount of gravitational attraction between objects, like between the Earth and a human body, depends of the size of the objects. Some objects, like the Earth and the Sun, have a lot more gravity than others because of their large masses. Gravity also depends on how close the objects are to each other. The closer objects are, the stronger the gravity between them.

Weight is a measurement of the force of gravity acting on an object. Your weight on Earth is how much force the Earth's gravity has on you and how hard it is pulling you toward the surface. We measure weight in units of pounds (lbs) or kilograms (kg) using a scale. Objects with more mass will have more weight on Earth. The same object on the moon will weigh less because the moon has less gravity than earth because it's smaller.

A short reading about GRAVITY

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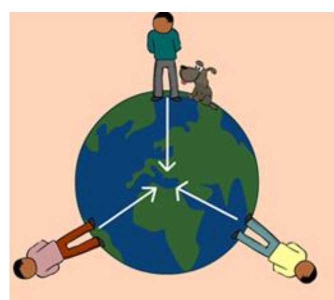

Gravity is a pulling force that makes everything fall towards the Earth. The amount of gravitational attraction between objects, like between the Earth and a human body, depends of the size of the objects. Some objects, like the Earth and the Sun, have a lot more gravity than others because of their large masses. Gravity also depends on how close the objects are to each other. The closer objects are, the stronger the gravity between them.

Weight is a measurement of the force of gravity acting on an object. Your weight on Earth is how much force the Earth's gravity has on you and how hard it is pulling you toward the surface. We measure weight in units of pounds (lbs) or kilograms (kg) using a scale. Objects with more mass will have more weight on Earth. The same object on the moon will weigh less because the moon has less gravity than earth because it's smaller.

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LESSON 5: Testing How Varying Pulling Force Affects Motion of Loaded Vehicle (Extension of Kit Lesson 4)

Objectives and Overview

In lesson 4, students initially used the 2-block load to find out how many washers it would take to get that load moving. Then that force (number of washers) stayed constant throughout the activity in lesson 4. The constant is force for all car load conditions (empty, 1-block, 2-block). The variable is the load. Lesson 4 gives us information about how when pulling with a constant force, the heavier vehicle takes more time to get moving.

In lesson 5, students will see the minimum force it takes to get each load moving (empty, 1-block, 2-block). They will observe that it takes less force to move less mass (empty car) and more force (more washers) to get the heavy car moving. Though some of these ideas overlap with lesson 4, both these activities help students understand that heavier loads require more force to get moving, keep moving, and stop moving.

- Students measure the force it takes to get different loads moving.
- Students draw and model pairs of opposing forces to explain changes in motion.

Next Generation Science Standards (NGSS)

Disciplinary Core Idea (DCI):

- **PS2.A Forces and Motion** - The effect of unbalanced forces on an object results in a change of motion

Science and Engineering Practice (SEP):

- Develop and use models - Develop a model using an analogy, example, or abstract representation to describe a scientific principle

Cross-Cutting Concept (CCC):

- **Cause and Effect** - Students identify causal relationships and use these relationships to explain change

Materials (See curriculum guide pgs 35-45, same materials as used in lesson 4)

Lesson

1. **Focus Question**: Introduce today's question that is related to the question in the prior lesson but slightly different (focusing on force rather than load): **What is the relationship between the weight of the vehicle and how much force is needed to get it to start moving?**

2. **Collect data**: Repeat the same set-up as Lesson 4 except instead of using the same number of washers on all 3 cars (empty, 1-block, 2-block) students will see just how many washers it takes to get the car moving depending on the car's mass (empty, 1-block, 2-block).

3. **Interpret and explain results**: Create a class data table and graph to display this relationship between load (blocks on car) and force (washers).

a. Discuss overall trends in data. Students can look at the graph and pair-share about what they see: **What do you see from the graph? What does this tell us about our focus question for today?**
b. Discuss any difficulties students had in getting their car to move – this conversation could go in different directions, for example:
   i. Getting consistent results might be hard, what would account for differences between groups? (experimental design)
   ii. Getting the car to move was hard sometimes and students observed "sticking points" between the wheel and axle (science content – friction)
   iii. Getting the heavy car to move and running out of small washers (needing big ones) – (science content – energy & force)

4. **Just-in-time Instruction: Energy & Force**
   a. Students will have multiple opportunities to learn about energy and energy transformations in this unit but it is introduced here. Tell students:

"Moving objects have a type of energy called kinetic energy. Kinetic energy is the energy of motion. The more kinetic energy something has, the faster it moves. When objects slow down, their kinetic energy is changed into another type of energy, such as heat energy or sound energy. Objects at rest have no kinetic energy."

   b. Have them think about that statement as it applies to our activities or to something in their lives they've noticed. **How does what we just heard about energy explain what we observed in this activity?** Think-pair-share. Discuss as a class how energy and force are related.
   c. We have previously represented force using pairs of arrows. How can we show energy in a model? We also can't see energy. Decide as a class on one way to show energy (or a few ways as long as students articulate why they choose a particular way)
   d. Draw the forces and energy of either the car scenario from this activity OR the skateboarder.

5. **Summarizing what we've learned**:
   a. Use student input to complete a summary table row entry for this activity. An example is noted below.

Possible Summary Table Entry:

What Did we DO?	Observations	Learning	So What?
Getting Going	It takes more force (more washers) to get 2-block load to move than an empty car.	More forces is needed to start and stop heavier objects.	If the boy was wearing a loaded down back pack or were a bigger kid, his fall would have hurt more because it would take more force to stop him. He would also have to push more (use more force) to get moving.

LESSON 6: Looking at Friction (Revised kit lesson 8 pg 73-78)

Objectives and Overview

In the previous lessons, students explored the effects different forces on the same load, and then the idea that it takes less force to move a lesser load. Students will now observe the effects of friction on the motion of their car by pulling their car on different surfaces. Then, they will apply what they have learned about friction to reflect on the skateboarder phenomenon.

- Students describe the effects of different surfaces on getting a car to start moving, keep moving, and stop moving.
- Students share their observations of vehicle design features and the role of friction in vehicular motion.

Next Generation Science Standards (NGSS)

Disciplinary Core Idea (DCI): **PS2.A Forces and Motion & PS2.B Types of Interactions** -The effect of unbalanced forces on an object results in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact

Science and Engineering Practice (SEP):**Plan and carry out investigations** - Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered

Cross-Cutting Concept (CCC): **Patterns** – Use charts to identify patterns in data

Materials (see curriculum guide pg 73-79)

Lesson Directions

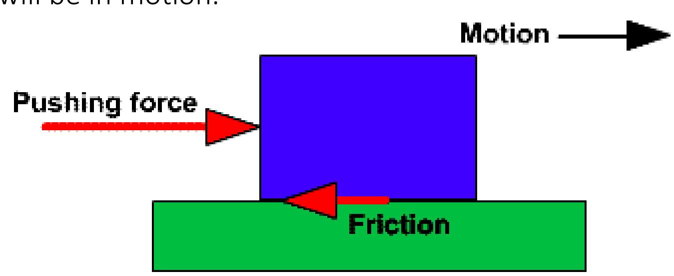
1. **Observing friction**: Follow lesson as written. Skip page 3 of recording sheet 8-A and instead of looking at the crossbars and frame, students observe tires and axles to observe different car loads on different surfaces and record descriptive information. Also, discuss everyday experiences about biking, rollerblading, or walking on different surfaces and how that affects motion. Have students test their standard cars on each surface.
2. **Plan an investigation:** Set up test areas for students to pull their car along the carpet, tile, table top or other surfaces and describe the relative force required to get moving. Students must decide how to design their experiments and what data to collect:
   a. *How will they pull with the same force on each surface?* Students may wish to use a similar washer-weight-string set-up as they did in prior activities and use a set number of washers.
   b. *How will they measure differences in car movement on different surfaces?* For example, they could use the time to measure how long it takes (time) the car to get going when pulled with the same force on each surface OR they could measure how far the car travels (distance) using the adding machine tape.

c. *What data do they need to record and how will they do it?*

~~~ Pause the lesson here after students decide how to do the experiment and the next session have students collect data about car performance on each surface.~~

3. **Data Collection**: Students conduct their friction investigations and collect their data. If time permits, students can create a lab report showing their data and results of what they found.

4. **Just-in-time instruction: Friction is a stopping force.**
   a. Introduce the word '**friction'**. Some students may have already used it or have tentative understandings of this term. Now is the time as a class to have everyone learn more about the word and how it affects the motion of their cars.
      i. Choose a video option. Have students watch the clip(s) to learn about friction. Pause if needed to discuss what the video says about friction.
         1. Friction Bill Nye Clip posted by Megan Early (03 min 05 sec) https://www.youtube.com/watch?v=MAqrWvkBoHk
         2. What is Friction? Dragonfly Education (03 min 02 sec) https://www.youtube.com/watch?v=x_24FBNa788
   b. The idea of balanced and unbalanced forces is key for this unit. Friction is a stopping force (see diagram below) which slows or stops motion in the opposite direction caused by pushing or pulling an object. If the forces of friction and the pulling are equal then the object will not be in motion. When the force of the motion from the push or pull is stronger than friction between the objects then the object will be in motion.



   c. Come up with a class definition of *friction* based on the video(s) and what students already may know. Students may bring in many ideas about how to reduce friction or stickiness (like applying oil or grease) or how a water slide is more slippery (has less friction) compared to playground slide.
   d. **Students draw a zoom-in between two surfaces:** *What does the friction look like between two surfaces?* Have students choose the rubbing situation to draw (i.e. between the wheel and axle, between the wheel and carpet, between the wheel and tile/desk). Include two arrows, one for friction and one for motion (like the videos show). After sketching these surfaces and what is happening between two things students choose.
~~~

i. What would it look like if you had 'microscope eyes' and could see the contact between surfaces?
ii. How would a smooth surface look i.e. tile) look different than a rough surface (i.e. sandpaper or carpet)?

5. **Interpreting Data Collection**:
   a. Students return to their data from their investigations and discuss the following questions in their small groups. Write the question on the board:
   How does what you know about friction help explain the results from your experiment?
      Possible sentence stems:
      1. Our data shows ___________. This means that there is friction between ______ and _____ because…
      2. In our experiment we tested ___________. If friction increased/decreased then…
   b. Have students work in their small groups to answer the question about how friction helps explain their data. Circulate the room to help groups get started. Here is a progression of questions to ask if students seem stuck:
      i. What did you test? (Recap their investigation question)
      ii. What did you find out? (Recap data)
      iii. Where can you find the friction in your car system? (i.e. between wheel and axle, between wheel and tile, between wheel and carpet)
      iv. What would change about your results if you increased (or decreased) the friction (at a particular point)?

6. **Summarizing what we've learned:** Work with students to fill out the summary table row based on this activity investigating how friction affects motion.

Possible Summary Table Entry:

What Did we DO?	Observations	Learning	So What?
Looking at Friction	Spinning Wheels have to touch the axle. If the axle is sticky or crooked, the wheels won't roll as well. Also, we observed that dragging the car on carpet is harder than on the table.	Higher friction between two touching things slows down or stops motion. Friction is a force between two touching objects that can be described as rubbing or sliding	If the skateboarder had muddy wheels he couldn't go as fast because the friction of the mud between the axle and the wheel would slow down the wheels rolling. When he lands successfully, he would eventually roll to a stop because the friction between the concrete and his wheels would eventually pull him to a stop.

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LESSON 7: Looking at Rubber Band Energy (Same as Kit Lesson 6)

Objectives and Overview

In previous lessons, students explored the motion of their vehicles when pulled by a weighted string. They will begin to explore another way of making their vehicle move— by releasing energy stored in a twisted and stretched rubbed band (potential energy) and using it to turn the axle, leading to moving the car (kinetic energy).

- Students attempt to move their vehicle using rubber band energy
- Students will be able to define "stored energy" (Potential energy) and "motion energy" (kinetic energy)

Next Generation Science Standards (NGSS)

Disciplinary Core Idea (DCI): **PS3.A Definitions of energy & PS3.B Conservation of Energy and Energy Transfer** - Moving objects contain energy. The faster the object moves, the more energy it has. Energy can be moved from place to place by moving objects, or through sound, light, or electrical currents. Energy can be converted from one form to another form. **PS3.C Relationship between energy and forces** - When objects collide, contact forces transfer energy so as to change the objects' motions.

Science and Engineering Practice (SEP): **Analyze and interpret data** - Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings

Cross-Cutting Concept (CCC): **Energy and matter** - Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations

Materials (see curriculum guide pgs 57-64)

Lesson Directions

1. **Observing energy transfers**: The 'Rubber Band Car' activity gets at the energy transformation story from stored energy (potential energy) stored in the twisted rubber band to energy of motion (kinetic energy) as it moves and then into sound energy when it hits the bookend. Have students follow the recording sheet provided in the curriculum guide to get comfortable using the rubber band to power their car and make observations about the rubber band.

2. **Just-in-Time Instruction**: Different forms of energy & energy transfer
   a. This activity gets at the energy transformation story from stored energy (potential energy) stored in the twisted rubber band to energy of motion (kinetic energy) as it moves and then into sound energy when it hits the bookend.
   b. Show a short video clip describing different kinds of energy and how energy is transferred. -- Energy Transformations by D Watson (watch from 0:00 – 3:30 only) https://www.youtube.com/watch?v=bUUyIS65xXk
   c. Define the following terms based on information in the video as a class:
      i. Kinetic energy – energy of motion
      ii. Potential energy – stored energy (or not moving by ready to do work)
      iii. Transformation – energy changes from one form to another

3. Lesson closing assessment - Think-Pair-Share-Write/draw: Take what we've learned from the video about types of energy and energy transformations to tell the energy stories for:
      i. Rubberband car (from activity)
      ii. Skateboard jump (from unit phenomenon)

(No summary table for this lesson. Lessons 7 & 8 are both about the rubber band car and potential to kinetic energy transfers so there is one summary table row for both of these lessons. Use what you hear and see from step 3 above to plan instruction in the next lesson that continues these ideas about energy transformations).

LESSON 8: Testing the Effects of Rubber Band Energy (Same as Kit Lesson 7)

Objectives and Overview

The 'Rubber Band Car' activity gets at the energy transformation story from stored energy (potential energy) stored in the twisted rubber band to energy of motion (kinetic energy) as it moves and then into sound energy when it hits the bookend.

- Students observe and describe the relationship between the number of turns of the rubber band around the axle and the distance their vehicle travels.
- Students learn more about the transfers and transformations of energy within a system.

Next Generation Science Standards (NGSS)

Disciplinary Core Idea (DCI): **PS3.A Definitions of energy & PS3.B Conservation of Energy and Energy Transfer** - Moving objects contain energy. The faster the object moves, the more energy it has. Energy can be moved from place to place by moving objects, or through sound, light, or electrical currents. Energy can be converted from one form to another form. **PS3.C Relationship between energy and forces** - When objects collide, contact forces transfer energy so as to change the objects' motions.

Science and Engineering Practice (SEP): **Analyze and interpret data** - Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings

Cross-Cutting Concept (CCC): **Energy and matter** - Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations

Materials (See curriculum guide pg 65-72)

Lesson Directions

1. **Data collection**: Follow curriculum guide 'Rubber Band Car' activity (curriculum guide lesson 7). After students collect their data (number of rubber band turns and distance travelled). As students work in small groups to collect data, circulate among the groups and ask one or more of the following questions:
   a. What makes the car go? How does the rubber band make it go? Where does that energy come from?
   b. What do you notice about how the number of turns affects the car? What's the maximum number of turns the rubber band can handle?

2. **Data presentation**: In small groups, find a way to represent your data. Students may decide to make a graph or data table. Post representations on the board and have students look across all data representations.

a. Think-Pair-Share: What are the similarities? What conclusions can we draw about the relationship between the number of rubber band turns and the distance the car travelled?
b. Think- Pair-Share: What are the differences? Why might groups have gotten different data?

~~~~ This is a good place to break the lesson if needed. ~~~~~~

3. **Just-in-time instruction**:
   a. This activity gets at the energy transformation story from stored energy (potential energy) stored in the twisted rubber band to energy of motion (kinetic energy) as it moves and then into sound energy when it hits the bookend.
   b. Show a short video clip describing different kinds of energy and how energy is transferred. -- Energy Transformations by D Watson (watch from 0:00 – 3:30 only) https://www.youtube.com/watch?v=bUUyIS65xXk
   c. Define the following terms based on information in the video as a class:
      i. Kinetic energy – energy of motion
      ii. Potential energy – stored energy (or not moving by ready to do work)
      iii. Transformation – energy changes from one form to another
   d. Think-Pair-Share: Take what we've learned from the video about types of energy and energy transformations to tell the energy stories for:
      i. Rubberband car (from activity)
      ii. Skateboard jump (from unit phenomenon)

4. **Summary Table**: Spend time having students share how they think the rubber band car is like the skateboarder and fill in the summary table row for this activity paying attention to the energy transfer and transformation story.
   - What would represent the muscles? (rubber band)
   - How do our muscles get energy? (from food)
   - So if we tell the energy story, students should trace the energy from food to energy stored in muscles, then muscles transform energy into motion to push the skater along to get moving, energy of motion transferred to spinning wheels, etc. The energy story continues to the crash of the car into the bookend (converting motion energy to sound) or with the skateboarder

Summary Table

What Did we DO?	Observations	Learning	So What?
Rubber Band Car	By increasing twists, the speed of the car increases.	The twisted rubber band stores energy and it only gets used if the rubber band is allowed to untwist. Energy can be converted or changed within a system. Stored energy (potential energy)→motion energy (kinetic energy) → sound energy	The skateboarder will move faster if he pushes with his leg muscles harder on the ground. There is energy in his muscles from food that he can use to skateboard. Food (Chemical Energy)→ Motion Energy→ sound energy (hitting bookend or the crash) + some heat energy (from friction – very little)
~~~~

Just-in-Time Instruction – Center of Mass

Your students may need this lesson guide to better understand why the skateboarder falls over. It is placed in the guide after lesson 8, but could go earlier in the unit. Use your discretion as to where you think it would best fit for your students.

Materials:

- empty cereal box
- 3-4 blocks from the kit
- Video clip https://www.youtube.com/watch?v=2VpzHJ_R55I
- student sheet (1 per student)

Lesson:

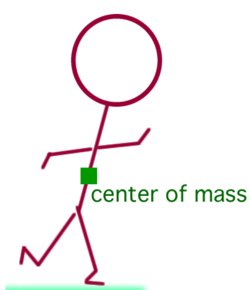
1. **Making observations:**
    a. Prior to class, stack blocks inside one corner of an empty cereal box and close it. You are shifting the center of mass of the box so that the box will not fall off the table when students think it should. Set it on a table at the front of the room.
    b. As students enter class, open with the essential question: **Why does the skateboarder fall over? For that matter, why does anything fall?**
    c. Then have students observe as you slowly push the cereal box over the edge of the table. They will be surprised it does not fall when they think it should. Have students turn-and-talk about what they saw and why they think it happened.
        i. Where do you think the box should be when it starts falling?
        ii. What might be going on inside to make it not fall until much later?
    d. Share out some ideas in a whole class setting

2. **Feeling the fall:**
    a. Have students stand with their backs to a wall and their heels against the wall/baseboard. Ask them to bend forward and touch their toes. The hallway or outside against the school building is a good place to do this.
    b. Have students do it again really pay attention about how it feels. Where do you feel the pressure in your feet as you slowly bend forward? At what point do you feel as if you are just about to fall? Pay attention to where your belly button is in relation to your feet.
    c. When students step away from the wall they can touch their toes because the body shifts back redistributing to keep the mass over the feet. When the wall is

in the way, we can't lean back and so our mass shifts too far over our feet and we fall.

3. **Just-in-time instruction: Center of Mass**
    a. Return to the classroom and explain to students that every object has a center of mass. This is sometimes in the middle of an object but can also be to one side like in our tricky cereal box.
    b. Watch this video clip: Center of Mass Science Theater 29 https://www.youtube.com/watch?v=2VpzHJ_R55I
    c. When the center of mass is over the base (feet, table, etc) then the object is balanced. When the center of mass goes past the base (feet, table, etc) then the object will fall because there is no longer a reaction force pushing up that is equal to the weight pulling down.
    d. Have students pair-share to use the concept of center of mass to explain the cereal box trick.

4. **Closing**: Students individually complete the student sheet to use force arrows and the idea of center of mass to explain the cereal box trick and also to answer the essential question for this mini-lesson about why the skateboarder fell forward.



Center of mass – a point within a person or object where average of the mass or weight is centered

Name: ______________________________________ Date: _________

Observe & Learn: Cereal Box Demonstration

- ☐ Draw and label what you observed.
- ☐ Include pairs of force arrows to explain motion.
- ☐ Also label the center of mass to explain what happened.

Write to explain your thinking:

Connect to the Skateboard Jump: Use the idea of center of mass to explain why the skateboarder falls forward.

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LESSON 9: Adding to Models using Evidence from Activities

Objectives and Overview

It is important for students to revise their ideas over time in light of the new experiences, observations, and sense making talk that they have had throughout the unit activities. This model revision and talk will help students with writing an evidence-based explanation about how forces affect motion in the next lesson.

- Students use what they've learned so far using the summary table to develop and revise their initial ideas on a model scaffold to show their new learning.

Next Generation Science Standards (NGSS)

Disciplinary Core Idea (DCI):

PS2.A Forces and Motion & PS2.B Types of Interactions

- The effect of unbalanced forces on an object results in a change of motion.
- Patterns of motion can be used to predict future motion.
- Some forces act through contact, some forces act even when the objects are not in contact.
- The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center

PS3.A Energy & PS3.B Conservation of Energy and Energy Transfer

- Moving objects contain energy. The faster the object moves, the more energy it has.
- Energy can be moved from place to place by moving objects, or through sound, light, or electrical currents.
- Energy can be converted from one form to another form.

PS3.C Relationship between energy and forces

- When objects collide, contact forces transfer energy so as to change the objects' motions.
- When two objects interact, each one exerts a force on the other, and these forces can transfer energy between them.

Science and Engineering Practice (SEP):

- **Developing and Using Models** - Develop a model to describe unobservable mechanisms.
- **Creating Explanations** - • Identify the evidence that supports particular points in an explanation

Cross-Cutting Concept (CCC):

- **Cause and Effect** - Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

Materials

For class reference:

- Summary Table poster filled in with learning from activities
- Chart paper for a diagram convention poster (developed as a class)
- Explanation checklist (developed as a class)

For each pair:

- Blank model scaffold sheet
- Pencils with erasers (colored pencils optional)
- Student copy of Summary Table (optional)
- Initial Model done in lesson 1

Lesson

1. Re-orient students to the focal models and hypotheses.
    a. Before class review students' initial models and/or students' hypotheses.
    b. Consider one or two of these opening questions:
        - "This is what our groups have been thinking about—what is it we have been trying to represent?"
        - "What is the puzzle we are trying to solve?"
        - "What are we trying to explain?"

       Students may say, for example, "We are making a model of a skateboard jumping," but you need to re-name the model in terms of the underlying idea – in this case we are modeling the "relationship between forces and motion." (And a story of energy transformation, too!)
    c. Re-articulate the original "why" question you posed as an essential question earlier in the sequence of lessons.

2. Prepare students to work on models:
    a. Develop a "gotta have" checklist. What are the 2-3 big relationships that you want to make sure students include? What are the ideas students think they should be including. Ask the following question and provide time for Think-Pair-Share and then share out to make a list of no more than 4 big ideas you and students think they need to remember to include.
       "If you were going to tell any motion story - whether it's our skateboard jump story or a student tripping in the hallway, riding a bike, pushing shopping cart, running a race, whatever motion story - what would be some key ideas or concepts that we would have to or "gotta have" in order to explain how motion works?"

       Sample Explanation Checklist:

       - ☐ How pushes and pulls make motion happen
       - ☐ how unbalanced forces change motion
       - ☐ how energy transforms or changes through motion
       - ☐ how unobservable forces and energy affect objects
       - ☐ forces come in invisible pairs

    b. Optional, but could be useful: Prior to releasing students work on model revisions you may decide to create a possible key for the models where certain symbols represent different forms of energy (or colors, if using colored pencils).

3. Partners work on their new skateboard jump models.
    a. In this step you ask pairs of students to provide an explanation for a phenomenon by updating their model on a new scaffold using diagram conventions you have decided on as a class. Refer students to the summary table to remind them what evidence and ideas they have collected from the activities.
    b. Teacher checks in with partners to see if they are attending to all parts of the model. When you visit tables, make sure students are started on reasoning through a question together before you leave the table, this way intellectual conversations won't just happen when you are present. Ask some back pocket questions such as:
        - "I hear you are thinking about X and Y ideas, what about Z? How does it fit in? I'll be back in a few minutes to hear your ideas."
    c. Walking the room and looking at student model revisions gives a sense of which student pairs are focused on which ideas. Select 2 pairs of students whose models may emphasize different parts of the explanation to show their model under the document camera.
    d. Pause student work and have each pair take a few minutes to explain their ideas and evidence for those ideas. Other students can make suggestions of things they could add or ask them about the evidence they use to make the claims. These examples you select may feature ideas you want all students to consider so prompt them to do so after seeing these examples.
    e. Resume partner work on models to add, clarify, or change in light of what they saw from their peers.

4. Asking questions to pairs/groups of students, looking at student model revisions and listening to student talk shows how students are thinking about the science explanation now. Use what you hear to think about questions that help students get at parts of the explanation they are missing.

5. Closing: Pass out original models from lesson 1. Have students use sticky notes to mark at least 1 place where their thinking has changed and identify what activity or experiences made that thinking change.
   My thinking about _____ changed because…
   I used to think ________ but now I think …

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LESSON 10: Writing the Evidence Based Explanation

Objectives and Overview

Now that students have updated their models, and had time to talk through the explanation, it is time to focus on pairing evidence with their ideas and writing in a logical order to tell the force-and-motion story and the energy-story of the skateboard jump example.

- Students write an evidence based explanation that describes the forces and motion involved in the skateboard story.

Next Generation Science Standards (NGSS)

Disciplinary Core Idea (DCI):

PS2.A Forces and Motion & PS2.B Types of Interactions

- The effect of unbalanced forces on an object results in a change of motion.
- Patterns of motion can be used to predict future motion.
- Some forces act through contact, some forces act even when the objects are not in contact.
- The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center

PS3.A Energy & PS3.B Conservation of Energy and Energy Transfer

- Moving objects contain energy. The faster the object moves, the more energy it has.
- Energy can be moved from place to place by moving objects, or through sound, light, or electrical currents.
- Energy can be converted from one form to another form.

PS3.C Relationship between energy and forces

- When objects collide, contact forces transfer energy so as to change the objects' motions.
- When two objects interact, each one exerts a force on the other, and these forces can transfer energy between them.

Science and Engineering Practice (SEP):

- **Developing and Using Models** - Develop a model to describe unobservable mechanisms.
- **Creating Explanations** - Identify the evidence that supports particular points in an explanation

Cross-Cutting Concept (CCC):

- **Cause and Effect** - Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

Materials

For class reference:

- Summary Table poster filled in with some (ideally all) activities
- What-How-Why writing examples sheet
- Explanation checklist (created with students, ideally, or by the teacher)

For each pair:

- Revised Model (from lesson 9)
- Writing Springboard (or sentence starters displayed on the board or at each table)
- Notebook paper
- Pencil with eraser
- Sticky notes

Lesson

1. Explain that scientists don't just do experiments only for fun but they have the purpose of collecting evidence that supports, or not, particular ideas or hypotheses, just like students have done over the past several lessons. The summary table serves as a record of the evidence collecting. Writing evidence-based explanations helps us better understand how our world works and also communicates our ideas to others if we aren't there to talk it through.

2. In the writing task today, students (in pairs, if you like) will either choose or teacher can assign ONE part of the story (beginning, middle, end) they will explain in depth. For example, students may only focus on beginning panels for both jumps. Students will use their model revision to inform what they write about this particular part of the jump.

3. Students should explain their observations about the motion for their particular part of BOTH jumps (comparing and contrasting), if the forces are balanced, which forces are involved, the evidence they have that helps explain these forces (talking about the k'nex car with blocks and washer pulling). Use the "What-How-Why Writing Examples" sheet to show students what you mean. Also, use an explanation checklist (list of things students must discuss in their explanation).

4. Give students time to use sentence starters to compose observation + ideas + evidence to explain the successful versus failed jump in terms of how forces affect the motion of the object.

5. Pair up 3 pairs (beginning, middle, end) into groups of 6 students. Students listen to each pair read their explanation draft of that part of the model. Pair 1 can read the 'beginning', pair 2 can read their explanation of the 'middle' and pair 3 can read the 'ending' explanation. Then use sticky notes to suggest things to add to each others parts as they listen. As a group of 6 then, they should have a full explanation.

After the lesson:

Use the teacher-version of the explanation included in the teacher background at the beginning of this unit guide to check to see if the group of students have addressed things like:

- What makes forces balanced or unbalanced?
- How do balanced and unbalanced forces explain the successful jump and failed jump?
- How does object's mass affect force needed to stop or start its motion?
- How does energy change (transforms) from the energy in the skater's breakfast to the noise he makes when he lands (or crashes) after the jump?

Writing Extension Option:

If you teach science and writing you can extend this writing activity and have students come up with a rubric using the explanation checklist in order to provide peer feedback to each other about how to strengthen the use of evidence and writing traits.

Writing The "Skateboarder Jump" Explanation

In your writing, you need to:

1. Explain the motion of the skateboarder using the different forces that act on him. (Think about pushing, pulling, gravity, friction.)
2. Describe what <u>energy transformations</u> happen during the skateboarders jump. (Also, share how you think these transformations happen.)
3. Use evidence from the summary table to support your ideas.

"Gotta Have" Checklist: **What ideas do we "gotta have" in order to explain why our skateboarder fell?**

- ✓ How unbalanced forces cause different types of motion (starting, rolling, jumping, falling, stopping).
- ✓ Why stopping fast hurts more than stopping slowly.
- ✓ How friction affects skateboard motion.
- ✓ How energy changes (transforms) from the energy in the skater's breakfast to the noise he makes when he lands (or crashes) after the jump.

For each idea you state in your explanation, what <u>evidence</u> do we have to support it?

- My evidence for this idea is …
- This idea is supported by the activity where we …
- When we did ________________________, it showed us that ____________________ so therefore that supports my idea about__________ because __________________.

Write a "WHY" level explanation.

WHAT happens?

Observations Only

HOW does it happen?

Observations + Ideas

WHY does it happen?

Observation + Idea + Evidence

Writing The "Skateboarder Jump" Explanation

In your writing, you need to:

1. Explain the motion of the skateboarder using the different forces that act on him. (Think about pushing, pulling, gravity, friction.)
2. Describe what <u>energy transformations</u> happen during the skateboarders jump. (Also, share how you think these transformations happen.)
3. Use evidence from the summary table to support your ideas.

"Gotta Have" Checklist: **What ideas do we "gotta have" in order to explain why our skateboarder fell?**

- ✓ How unbalanced forces cause different types of motion (starting, rolling, jumping, falling, stopping).
- ✓ Why stopping fast hurts more than stopping slowly.
- ✓ How friction affects skateboard motion.
- ✓ How energy changes (transforms) from the energy in the skater's breakfast to the noise he makes when he lands (or crashes) after the jump.

For each idea you state in your explanation, what <u>evidence</u> do we have to support it?

- My evidence for this idea is …
- This idea is supported by the activity where we …
- When we did ________________________, it showed us that ____________________ so therefore that supports my idea about__________ because __________________.

Write a "WHY" level explanation.

WHAT happens?

Observations Only

HOW does it happen?

Observations + Ideas

WHY does it happen?

Observation + Idea + Evidence

Remember to try to write a "WHY" level explanation. This is difficult to do, so use the evidence tables in your notebook as well as posters in the classroom to help remind you of all the evidence we have collected about the SKATEBOARD JUMP.

"What" Level

I observe that…

In science class we…

"How" Level

I observe that…

In science class we… which showed me evidence that…

"Why" Level

I observe that…

In science class we… which showed me evidence that…

Even though I can't observe ________
I think it is happening because…

If you write at the "What" Level you only describe what happens like observations and what you did in experiments.

Short Example:
When the skater stands on the board and pushes down and back with his foot, they both move forward. I observed that he leans back and the front wheels come up. He jumps into the air. The first time he lands and rolls to a stop. The second time he jumps I saw that he doesn't land right and falls forward because his body keeps going.

If you write at the "How" Level you describe observations PLUS how you think the things you observe happened using evidence.

Short Example:
When the skater stands on the board, he doesn't move. In class, I observed that the k'nex car was motionless when nothing was pulling it. That's evidence that the forces are balanced because it is not moving. The skater pushes on the ground and moves forward. This push force gets the skater moving just like the washer weight pulled the k'nex car to get it going.

If you write at the "WHY" level you explain why something happened. You tell the full story using observations and evidence about what is happening we can't observe.

Short Example:
When the skater stands on the board, he won't move. The forces are balanced. Gravity pulls the body down to the board and the board pushes up. There aren't any sideways pushes or pulls to make it unbalanced. In class, the teacher stood on the skateboard and was balanced. She didn't move. Also the k'nex car didn't move unless washers were added as weight to pull it sideways. When he puts his foot down to push, the chemical energy stored in his body turns into motion energy. The push makes him move because there's nothing there to stop the motion forward.

IN THE BEGINNING

In the beginning, the skateboarder stands still on the board. This happens because…

Then, the skateboarder gets started moving when he…

In science class, we made the car move when…

This is like the skateboarder because..

IN THE MIDDLE

In the middle, the skateboarder is able to jump into the air because…

We know that the forces…

This is like when we ____________________ and found out that…

In the 2nd jump, the skateboarder lost contact with the board. We think this happened because…

The __________ activity taught us that…

IN THE END

At the end of the 1st jump, the skateboarder lands successfully because…

We know this must be so because we learned that..

At the end of the 2nd jump, the skateboarder falls forward because…

In science class, we did an experiment about ______ and found out that…

Therefore, we figured out that he fell because…