Motion & Design
Unit Revision
Pairs with STC Motion & Design Kit
Grade 5

Contents of this file:
1. Information about Ambitious Teaching Practices
2. Teacher Content Primer about a Sound Energy Phenomenon
3. Curriculum Guide for Sound Energy Unit
4. Next Generation Science Standards

Unit Synopsis:

Students watch a video clip of a skateboarder making a successful jump over a speed bump followed by a failed jump. They make an initial model of their ideas about how and why the skateboarder was successful and then failed the second jump. Over the course of the unit, students gather evidence from a range of activities using the cart and different loads to explore forces that help explain the skateboarding phenomenon. The scientific explanation behind this event includes big science ideas around energy transfer and balanced (and unbalanced) forces. Throughout the unit, students should have opportunities to create and revise their own models of this skateboarding event in light of new evidence from activities. Ultimately, the model and explanation students create is for the skateboarding event; however, students should also apply what they understand about forces to other phenomenon relevant to their own lives. (Examples may include: motion on a school bus without seatbelts, riding a bicycle, pushing a heavy or light shopping cart.)
Ambitious Science Teaching

We provide here a vision of ambitious teaching—teaching that is effective, rigorous and equitable. But more than that, we provide a framework of research-based teaching practices that are consistent with this vision and a wide range of tools that can transform how students learn in your classroom. The vision, practice, and tools will furnish a common language about teaching for a group of science educators committed to the improvement of teaching. You will be able to identify “what we will get better at” and how to get started.

Ambitious teaching aims to support students of all racial, ethnic, and social class backgrounds in deeply understanding science ideas, participating in the talk of the discipline, and solving authentic problems. This teaching comes to life through four sets of teaching practices that are used together during units of instruction. These practices are powerful for several reasons. They have consistently been shown through research to support student engagement and learning. They can each be used regularly with any kind of science topic. And finally, because there are only four sets of practices, we can develop tools that help both teachers and students participate in them, anyone familiar with the practices can provide feedback to other educators working with the same basic repertoire, teachers can create productive variations of the practices, and everyone in the science education community can share a common language about the continual improvement of teaching.

The four Ambitious and Equitable Science Teaching Practices are summarized in the below.

<table>
<thead>
<tr>
<th>Practices</th>
<th>What does it LOOK like?</th>
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</table>
| Planning for engagement with important science ideas | • Planning a unit that connects a topic to a phenomena that it explains (Chemical Reactions – Bike Rusting, Photosynthesis – Seed Becoming a Tree)  
• Teaching a topic within a real-world context     |
| Eliciting students’ ideas                         | • Asking students to explain HOW and WHY they think a phenomena happens (How did the bike change? Why did it change? What is happening at the unobservable level?) |
| Supporting on-going changes in thinking           | • Using ALL activities/lessons to explain the phenomena.  
• Giving students opportunities to revise their thinking based on what they’re learning |
| Pressing for evidence-based explanations           | • Allowing students to create a final model or explanation about the phenomena  
• Pressing students to connect evidence to their explanation |
Many teachers want to know what their classrooms should look like and sound like—they want to understand how to interact with their students about science ideas and students’ ideas. This is especially true now that the Next Generation Science Standards are being used in many states. As a result of the last 30 years of classroom research, we know enough about effective instruction to describe in clear terms what kinds of teaching practices have been associated with student engagement and learning. This research tells us that there are many ways that teachers can design and implement effective instruction, but that there are common underlying characteristics to all these examples of teaching that can be analyzed, described, and learned by professionals. These practices embody a new form of “adaptive expertise” that EVERY science educator can work towards. Expert teaching can become the norm, not reserved for a select few. Ambitious teaching is framed in terms of practices that any teacher can learn and get better at over time. What would we see if we entered classroom of a science educator using ambitious teaching? To give you a sense of what ambitious teaching looks like, we have described below some features common to all science classrooms where ambitious teaching is being implemented (listed on right). These features address everyday problems with learning and engagement that teachers face (listed on left).

<table>
<thead>
<tr>
<th>Common problems in supporting student engagement and learning</th>
<th>What you’d see in a science classroom where ambitious teaching is the aim</th>
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<tbody>
<tr>
<td>The problem: Students don’t see how science ideas fit together. Each day is perceived by students to be the exploration of ideas that are unconnected with previous concepts and experiences.</td>
<td>At the beginning of the unit, students are focused on developing an evidence-based explanation for a complex event, or process. Students know that throughout unit, most of the activities, readings and conversations will contribute to this explanation.</td>
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<tr>
<td>The problem: An oversimplified view of what it means “to know.” Science ideas perceived to be straightforward and learnable within a lesson—either you get it or you don’t.</td>
<td>An idea is never taught once and for all, but revisited multiple times. Students’ science explanations are treated as partial understandings that have to be revisited over time to become more refined and coherent.</td>
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<td>The problem: Lack of student engagement. Students’ experiences and interests not elicited or seen as relevant. Student ideas treated as “correct” or “incorrect.”</td>
<td>Students’ ideas and everyday experiences are elicited and treated as resources for reasoning; students’ partial understandings are honored as a place to start. They are made public and built upon.</td>
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<td>The problem: Students reluctant to participate in science conversations. Teachers dominate the talk, ask primarily for right answers, get brief responses from students.</td>
<td>Teachers use a varied repertoire of discourse moves to facilitate student talk. Guides and scaffolds for talk help students feel comfortable interacting with peers.</td>
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<td>The problem: Some students have little support for accomplishing tasks that would otherwise be within their grasp. Little or no guidance for students’ intellectual work. Giving “clear directions” is seen as enough to ensure participation in activities.</td>
<td>There is scaffolding that allows students to participate in science-specific forms of talk, in group work, and in science practices.</td>
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<td>The problem: Invisibility of student ideas and reasoning. Teacher does not know what students think—their heads are a black box. Cannot then work on students’ ideas. Students cannot take advantage of the ideas or ways of reasoning by their peers.</td>
<td>Students’ thinking made visible through various public representations (tentative science models, lists of hypotheses, question they have, etc.). The teacher can see how students think and how that thinking could change over time. Students benefit from seeing and hearing the reasoning of others.</td>
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<td>The problem: Illusion of rigor. Students reproduce textbook explanations, lean on vocabulary as a substitute for understanding. Talk of evidence and claims are rare.</td>
<td>The teacher presses for complete, gapless explanations for unique real-life events or processes, and press for the use of evidence to support claims.</td>
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As you will see, ambitious teaching is not a “method,” and the teaching practices are not scripts. It is a set of principled practices that must be adapted to your classroom needs. Coaches and other teachers can work with you to do this ambitious work.
This curriculum guide follows the four core teaching practices of the Ambitious Science Teaching Framework. This model-based inquiry approach to science teaching leverages students’ existing personal experiences and current understanding about causal mechanisms in their world to revise their own explanations of specific, contextualized scientific phenomena.

For more information about this teaching framework, visit this website [http://www.tools4teachingscience.org](http://www.tools4teachingscience.org)
# Motion & Design Unit Overview

**“MOTION”**  
Science Focus: Writing an Evidence-Based Explanation

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Connection to Kit Curriculum</th>
<th>Lesson Title</th>
<th>Suggested Time</th>
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<tbody>
<tr>
<td>1</td>
<td>ADDED NEW LESSON</td>
<td>Pre Unit Assessment: Developing Models to Explain the Skateboarder’s Motion</td>
<td>45-60 mins</td>
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<tr>
<td>2</td>
<td>REVISED KIT LESSON 2</td>
<td>Using Drawings to Build Standard Car</td>
<td>30-45 mins</td>
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<tr>
<td>3</td>
<td>SAME KIT LESSON 3</td>
<td>Pulling a Vehicle: Looking at Force</td>
<td>45 mins</td>
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<td>4</td>
<td>SAME KIT LESSON 4</td>
<td>Testing the Motion of Vehicles Carrying a Load</td>
<td>45 mins</td>
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<tr>
<td>5</td>
<td>ADDED NEW LESSON</td>
<td>Testing How Varying Pulling Force Affects Motion of Loaded Vehicle (Extension of Kit Lesson 4)</td>
<td>45 mins</td>
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<tr>
<td>6</td>
<td>REVISED KIT LESSON 8</td>
<td>Evaluating Vehicle Design: Looking at Friction</td>
<td>45-60 mins</td>
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<tr>
<td>7</td>
<td>SAME Kit Lesson 6</td>
<td>Looking at Rubber Band Energy</td>
<td>45 mins</td>
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<td>8</td>
<td>SAME Kit Lesson 7</td>
<td>Testing the Effects of Rubber Band Energy</td>
<td>45 mins</td>
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<td>9</td>
<td>ADDED NEW LESSON</td>
<td>Adding to Models using Evidence from Activities</td>
<td>45 mins</td>
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<td>10</td>
<td>ADDED NEW LESSON</td>
<td>Writing the Evidence-Based Explanation</td>
<td>60 mins</td>
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**“DESIGN”**  
Engineering Focus: Meeting Design Requirements  
(Use Kit Lessons 5 & 9-16)
NEW
Lesson 1

Overview and Objectives

This lesson introduces students to ways of observing and talking about force and motion using everyday language by using the “Skateboard Jump” phenomenon. It asks students to develop a model using their current level of understanding to explain why the skateboarder has success on his first jump and falls on the second jump.

- Students make observations and develop initial models to explain how skateboarder motion is caused by forces.
- Students record and share their ideas and questions about “Skateboard Jump”

Background

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.
   a. Successful. He lands and there are balanced forces again. He is coasting. The force of friction will eventually slow him down.
   b. 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 (KE=mv²). He then pushes himself up using more chemical energy. When he is up in the air he has potential energy, which is then converted into KE as he falls. 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

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<td>Pushing-forward/pushing force applied</td>
<td>Coasting velocity stays the same</td>
<td>Jump-up force applied</td>
<td>Free fall-gravity force pulls boy to the earth</td>
<td>Successful Landing- forces are balanced</td>
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**Successful ride**

- Standing still, at rest - balanced forces
- Pushing-forward/pushing force applied unbalanced
- 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
- Coasting velocity stays the same balanced
- Jump-up force applied unbalanced forces
- Free fall-gravity force pulls boy to the earth
- Epic Fail- forces are not balanced

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**For the class:**
- “Skateboard Jump” video
  [http://www.youtube.com/watch?v=2MUlhxkpIrw](http://www.youtube.com/watch?v=2MUlhxkpIrw)
- 1 Skateboard (bring from home or borrow a student’s)

**For each pair of students:**
- 1 model scaffold sheet (11” x 17”)
- 2 pencils with eraser (colored pencils optional)
- 1 photo card comparing freeze-frames of skateboard jumps
1. Introduce this motion and design unit using the 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. In order to focus our 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 the jump.

2. 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 (see below) 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?

End the lesson by explaining to students that they will be doing several investigations over the next few days to gather evidence for some of their ideas about the skateboarder’s motion. Name or call on specific pairs to describe their ideas (keeping big science ideas in mind.) Record a list of hypotheses students have identified as being important. This list should be revised as students gather evidence (it is a ‘rough draft’ that will be revised
Assessment over time. It can be messy with cross-outs, add ons, etc.)

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 really attending to energy transformations, when they engage 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.

PREVISED
Lesson 2

Using Drawings to Build a Standard Car

Overview and Objectives
In this lesson students will build a vehicle of their choice first as a way to explore the properties of the pieces and challenges to vehicle assembly. By the end of the lesson, each table group will have assembled a standard car they will use throughout the unit as a test vehicle.

- Students design their own vehicles to explore the materials.  
  (Notebook sketch optional)
- Students build a vehicle by following a two-view technical drawing

(See curriculum guide)

MODIFICATION: Students have not yet explored the materials or built their own vehicles. Instead of spending time drawing during this lesson, allow students time to “play” with materials to construct small vehicles and then pass out technical drawing of standard car. By end of lesson, each group will have a standard car.

Use Q1 pg 18

(After students complete their “standard vehicles” have students look around the room to see if all the 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.)

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.
### Lesson 3

**SAME**

**Pulling a Vehicle: Looking at Force**  
(see curriculum pgs 25-33)

### Lesson 4

**SAME**

**Testing the Motion of Vehicles Carrying a Load**  
(see curriculum pgs 35-45)

(See curriculum)

- How much time does it take for a different loads to move when pulled with the same force?

“What if” Scenario to try:

**What if** the skater 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?

### Lesson 5

**ADDED**

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

**Overview and Objectives**

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. 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 how much 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

- What is the relationship between the weight of the vehicle and how much force is required to get it moving?

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.

Continue the “what if” scenario about the heavy backpack.  
**What if** the skater were carrying a heavy backpack full of homework and textbooks? How is that like the 2-block car? Use the idea of force to talk about the skater wearing the backpack. How would the pushing force
required to get moving at the beginning be different with and without the backpack? (Draw parallel between empty car and 2-block car.) How hard did the loaded and unloaded cars hit the bookend? How would this compare to how hard the skater would hit the pavement with a heavy backpack?

**REVISED Lesson 6**

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

Follow lesson as written but skip page 3 of recording sheet 8-A. Instead of looking at the crossbars and frame, students will use what they have just observed about tires and axles to observe different car loads on different surfaces and record descriptive information.

Set up a data table for students to pull the car along the carpet, tile, table top or other surfaces in the room and describe the relative force required to get moving. Also, discuss everyday experiences about biking, rollerblading, or walking on different surfaces and how that affects motion.

**SAME Lesson 7**

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

The ‘Rubber Band Car’ activity really 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.

**SAME Lesson 8**

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

The ‘Rubber Band Car’ activity really 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. Spend time having students share how they think the rubber band car is like the skater. 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.
### Overview & Objectives

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.

For class reference:
- Summary Table poster filled in with some (ideally all) activities
- Diagram convention norm poster

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

### Procedures

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?”
      i. 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. Partners work at updating their model.
   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.

3. 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.”

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. 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.

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.

This model revision and talk will help students with writing an evidence-based explanation about how forces affect motion in the next lesson.

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.

For class reference:
- Summary Table poster filled in with some (ideally all) activities
- What-How-Why writing examples sheet

For each pair:
- Revised Model
- Writing Springboard (or sentence starters displayed either on the board or at each table)
- Notebook paper
- Pencil with eraser
- Sticky notes
Procedures

- 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.

- 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 for both jumps. Students will use their model revision to inform what they write about this particular part of the jump.

- 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.

- 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.

Final Activity

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.

Assessment

Use the teacher-version of the explanation included in lesson 1 overview to check to see if the group of students have included things like :

- What makes forces balanced or unbalanced? How does 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?
# Summary Table

*What evidence have we collected so far?*

<table>
<thead>
<tr>
<th>What did we do?</th>
<th>What did we observe? What patterns did we notice?</th>
<th>What did we learn from our observations?</th>
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</table>
| PULL THE EMPTY CAR                                                          | 1. Empty car rolled faster with more washers pulling it.                            | 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.                                                                                                           |
| Pulling an Empty Vehicle with Washers (KIT LESSON 3)                         | 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.                           |                                                                                                                 |                                                                                                                                                                                                                                                                  |
| SPEED OF LOADED CARS                                                        | 1. It takes more time for the heaviest loaded car to get moving when all cars are pulled with same force. | 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 time to stop his load/weight so he felt all the force almost at once.                                                                                       |
| Pulling a Loaded Vehicle with Washers (KIT LESSON 4)                        | 2. Car kept moving even if the washers stopped at the floor.                       |                                                                                                                 |                                                                                                                                                                                                                                                                  |
|                                                                             | 3. The heavy car hit the bookend harder than the empty car.                        |                                                                                                                 |                                                                                                                                                                                                                                                                  |
| GETTING GOING                                                               | 1. It takes more force (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 force to stop him. He would also have to push more (more force) to get moving.                                                                                                     |
| How much force does it take to get each vehicle to move?                   |                                                                                   |                                                                                                                 |                                                                                                                                                                                                                                                                  |
| (NOT IN KIT, EXTENSION OF KIT LESSON 4)                                     |                                                                                   |                                                                                                                 |                                                                                                                                                                                                                                                                  |
| LOOKING AT FRICTION                                                         | 1. Spinning wheels have to touch the axle. If the axle is sticky or crooked, the wheels won’t roll as well. | 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.                                                                                       |
| (KIT LESSON 8)                                                              | 2. Also, we observed that dragging the car on carpet is harder than on the table.  |                                                                                                                 |                                                                                                                                                                                                                                                                  |
| 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.        | 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                                                                                                                |
Success vs. Epic Fail: Our Model

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.

Successful Jump

“Epic Fail”

Compare the Start

Compare the Middle

Compare the Landing
TEACHER DIRECTIONS - CONSTRUCTING EXPLANATIONS

After students have engaged with several investigations from the curriculum revision, students have gathered evidence from observations about how different forces affect the motion of the car. This series of 5 lessons was chosen from the lessons in the kit specifically for how their conclusions about forces and motion can help explain pieces of the skateboard jump and fall. Students are asked in this lesson to coordinate what they have learned from the different car investigations to apply it to the skateboarder scenario and explain why the skateboarder is able to jump and/or performs an 'epic fail.'

TIP #1: Divide the Task.

Writing a complete explanation of both entire jumps with claims and evidence is a HUGE undertaking for individual students. Break up the phenomenon into pieces that then can be put together as a class or as a group to explain the whole jump. Here are a few options of ways to break the task down (feel free to come up with your own as well). (I personally prefer students to work in groups so they can have peer support in figuring out how to 'wordsmith' their writing.)

1. Have students choose one jump only to explain then pair-up with a partner to make a complete explanation:
   1. Why the successful jump worked using evidence from the car experiments
   2. Why the 'epic fail' jump didn’t work using evidence from the car experiments
2. Select, describe and explain 1-2 panels from each jump looking at what’s similar and what’s different and how that affects landing the jump – tying in evidence from car activities.
3. Work in groups of 4 and have each student write about one panel of for each jump - then put them all together into one big explanation. (You can write a paragraph about one panel (so all 5 are covered) to model how to use sentence starters and your writing expectations.)

TIP #2: Watch for vocabulary.

Students may still use a mix of science language and everyday language. If students use words like ‘friction’ or ‘gravity’ ask them to add in a sentence explaining what that force is and does and how that affects the skateboarder so they don’t just hide behind science vocabulary.

TIP #3: Sentence Strips: Helpful or confusing?

Students don’t have to use the strips if they feel confused or confined by the phrasing. They can rewrite them in their own words and add in extra sentences about ideas that are important that may not be included. They are a guide to help with writing, but should not impede progress if students can be more productive without them.
This sample shows just the beginning of a full explanation using sentence starters (storyboard, claim, evidence). However, student explanations will vary and should not all look identical.

SAMPLE: Beginning of Explanation (Student responses may vary.)

Before he starts moving, the boy has to stand on the skateboard. He isn't moving. *If the boy stands on the skateboard, he is not moving because* he hasn’t pushed off yet to get going. The forces are gravity pulling him down and the skateboard supporting him. But they are equal and there aren’t any sideways pushes or pulls to move him. *In the Getting Going activity, we observed* that the car wouldn’t move until there were enough washers on the string to pull the car to start it moving. The car still didn’t move at first because there wasn’t enough sideways force (like pushes or pulls) to get it to go.

Next, the boy has to be moving and get up some speed before the jump. *To get started moving, the boy must* push against the ground with his foot and push off *because* he won’t move unless he’s pushed or pulled. *In the Getting Going activity, we observed* that once there were enough washers on the end of the string, the weight pulled the car enough to get it to move.

When the boy jumps, he pushes off with his legs. The boy is pulled down to the ground *because* of gravity. Gravity is always pulling us and objects down to the Earth. The boy pushes off with his legs stronger than the pull of gravity, so he goes up. But when he’s in the air he can’t keep pushing because he can’t touch anything to push off of. So once in the air, the only force pulling on him is gravity so he comes down. *Our evidence for this idea is* that our teacher had us jump up and down, we observed that to jump higher we had to use more muscle and use more effort. But we always came back down so something must be pulling us down even though we can’t see it - that’s gravity.

*[For students, they continue, or working in groups they can combine paragraphs they write together to make a complete explanation. This is just to show an example of what using these sentence starters might look like.]*
Before he starts moving, the boy must stand on the skateboard.

Next, the boy has to get moving and build some speed before the jump.

When the boy jumps, he pushes off with his legs.

Now, the boy is in the air.

In the successful jump, the wheels of the skateboard land evenly and he smoothly glides away.

In the 'Epic Fail' jump, he does not land evenly and he falls forward.

The boy wasn’t wearing a backpack. But the jumps might look different if he did wear a heavy backpack.
If the boy just stands on the skateboard, he is not moving because...

To get started moving, the boy must _______________________ because ...

When the boy lands the jump, he coasts but then slows down to a stop because...

When the boy falls off the board, he falls forward not backward because...

The boy transforms food energy to motion energy to sound energy when he...

The boy is pulled down to the ground because ...

If the boy were wearing a heavy backpack, he would need ___more/less__ pushing force to get started rolling because...

If the boy were wearing a heavy backpack, he would jump ___higher/lower__ than he jumped without the backpack because...

If the boy were wearing a really heavy backpack when he fell, we think it would hurt ___more/less__ when he hit the ground because...

If the boy wanted to skate faster, he would need to ________________ because...
In the _____________ activity, we observed ______________________________ 
______________________.  This helps us explain __________________ because...

In the _____________ activity, we observed ______________________________ 
______________________.  This helps us explain __________________ because...

In the _____________ activity, we observed ______________________________ 
______________________.  This helps us explain __________________ because...

Our evidence for this idea is...

We know the skateboarder transformed motion energy into sound energy because in the ______________ investigation, we observed that...

Rolling objects will eventually come to a stop because of the force of _____________.
In the ______________ investigation, we observed that the car slowed down when ...

In the ______________ activity, we observed that the heavier car hit the bookend harder than the empty car. This helps us explain why...
**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 energy transformations 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 evidence 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.

<table>
<thead>
<tr>
<th>“What” Level</th>
<th>“How” Level</th>
<th>“Why” Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>I observe that...</td>
<td>I observe that...</td>
<td>I observe that...</td>
</tr>
<tr>
<td>In science class we...</td>
<td>In science class we... which showed me evidence that...</td>
<td>In science class we... which showed me evidence that...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Even though I can’t observe _______ I think it is happening because...</td>
</tr>
</tbody>
</table>

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

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

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

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

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

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 Knex 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.
Next Generation Science Standards (NGSS)

For more information about the Next Generation Science Standards, please visit this website http://www.nextgenscience.org/ There is also a free app available for smart phones and tablets.
5-PS2 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

5-PS2-1. Support an argument that the gravitational force exerted by Earth on objects is directed down. [Clarification Statement: “Down” is a local description of the direction that points toward the center of the spherical Earth.] [Assessment Boundary: Assessment does not include mathematical representation of gravitational force.]

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

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engaging in Argument from Evidence</td>
<td>PS2.B: Types of Interactions</td>
<td>Cause and Effect</td>
</tr>
<tr>
<td>Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s).</td>
<td>• The gravitational force of Earth acting on an object near Earth’s surface pulls that object toward the planet’s center. (5-PS2-1)</td>
<td>• Cause and effect relationships are routinely identified and used to explain change. (5-PS2-1)</td>
</tr>
<tr>
<td>• Support an argument with evidence, data, or a model. (5-PS2-1)</td>
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</table>

Articulation of DCIs across grade-levels: 3.PS2.A (5-PS2-1); 3.PS2.B (5-PS2-1); MS.PS2.B (5-PS2-1); MS.ESS1.B (5-PS2-1); MS.ESS2.C (5-PS2-1)

Common Core State Standards Connections:

ELA/Literacy –

RI.5.1 Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text. (5-PS2-1)

RI.5.9 Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably. (5-PS2-1)

W.5.1 Write opinion pieces on topics or texts, supporting a point of view with reasons and information. (5-PS2-1)
### 3-5-ETS1 Engineering Design

Students who demonstrate understanding can:

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

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### Science and Engineering Practices

#### Asking Questions and Defining Problems

- Asking questions and defining problems in 3–5 builds on K–2 experiences and progressions to specifying qualitative relationships.
- Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost. (3-5-ETS1-1)

#### Planning and Carrying Out Investigations

- Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progressions to include investigations that control variables and provide evidence to support explanations or design solutions.
  - 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. (3-5-ETS1-3)

#### Constructing Explanations and Designing Solutions

- Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.
  - Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design problem. (3-5-ETS1-2)

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### Disciplinary Core Ideas

#### ETS1.A: Defining and Delimiting Engineering Problems

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each meets the specified criteria for success or how well each takes the constraints into account. (3-5-ETS1-1)

#### ETS1.B: Developing Possible Solutions

- Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under conditions in which the criteria are met. (3-5-ETS1-2)
  - At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (3-5-ETS1-2)
  - Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3)

#### ETS1.C: Optimizing the Design Solution

- Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3-5-ETS1-3)

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### Crosscutting Concepts

#### Influence of Engineering, Technology, and Science on Society and the Natural World

- People's needs and wants change over time, as do their demands for new and improved technologies. (3-5-ETS1-1)
  - Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. (3-5-ETS1-2)

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### Common Core State Standards Connections:

**ELA/Literacy**

- **RI.5.1** Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text. (3-5-ETS1-2)
- **RI.5.7** Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently. (3-5-ETS1-2)
- **RI.5.9** Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably. (3-5-ETS1-2)
- **W.5.7** Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic. (3-5-ETS1-3)
- **W.5.8** Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources. (3-5-ETS1-1),(3-5-ETS1-3)
- **W.5.9** Draw evidence from literary or informational texts to support analysis, reflection, and research. (3-5-ETS1-1),(3-5-ETS1-3)

**Mathematics**

- **MP.2** Reason abstractly and quantitatively. (3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3)
- **MP.4** Model with mathematics. (3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3)
- **MP.5** Use appropriate tools strategically. (3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3)
- **3-5.OA** Operations and Algebraic Thinking (3-5-ETS1-1),(3-5-ETS1-2)
### MS-PS2 Motion and Stability: Forces and Interactions

**Science and Engineering Practices**

- **Asking Questions and Defining Problems**
  - Asking questions requires that students define a problem, define the variables involved, and identify the evidence that will help answer the question.
  - **Science and Enginee rin g Practices**
  - The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

**Disciplinary Core Ideas**

- **PS2.A: Forces and Motion**
  - Forces exerted by a moving object are not affected by the angle at which the force is applied.
  - The force exerted by the object on the first body is equal to the force exerted by the first body on the second body.
  - The force exerted by the object on the second body is equal to the force exerted by the first body on the second body.
  - The force exerted by the object on the first body is equal to the force exerted by the first body on the second body.
  - The force exerted by the object on the second body is equal to the force exerted by the first body on the second body.

- **PS2.B: Types of Interactions**
  - Electric and magnetic interactions can be attractive or repulsive, and their sizes depend on the distances between the interacting objects.
  - Electric and magnetic forces can be either attractive or repulsive, and their sizes depend on the distances between the interacting objects.
  - Electric and magnetic interactions can be attractive or repulsive, and their sizes depend on the distances between the interacting objects.
  - Electric and magnetic interactions can be attractive or repulsive, and their sizes depend on the distances between the interacting objects.

**Crosscutting Concepts**

- **Cause and Effect**
  - Cause and effect relationships may be used to predict phenomena in natural or designed systems.

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

- **Stability and Change**
  - Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

**Connections to Engineering, Technology, and Applications of Science**

- **Influence of Science, Engineering, and Technology on Society and the Natural World**
  - The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

**Connections to Nature of Science**

- **Scientific Knowledge is Based on Empirical Evidence**
  - Science knowledge is based upon logical and conceptual connections between evidence and explanations.

- **Articulation across designed world.**
  - Designed systems can be used to produce data to serve as the basis for evidence that can meet the goals of the investigation.

- **Constructing Explanations and Designing Solutions**
  - Constructing explanations and designing solutions to problems in 6-8 builds on K-5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- **Engaging in Argument from Evidence**
  - Engaging in argument from evidence requires students to communicate and behaviorally, in many cases, the quality of the reasoning from evidence.

- **Plan an investigation and evaluate the experimental design to provide evidence that supports or refutes claims for either explanations or solutions about the natural and designed world.**

- **Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.**

**Common Core State Standards Connections**

- **ELA/Literacy**

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*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.*

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| RST.6-8.1 | Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions (MS-PS2-1),(MS-PS2-3) |
| RST.6-8.3 | Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. (MS-PS2-1),(MS-PS2-2),(MS-PS2-5) |
| WHST.6-8.1 | Write arguments focused on discipline-specific content. (MS-PS2-4) |
| WHST.6-8.7 | Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-PS2-1),(MS-PS2-2),(MS-PS2-5) |

**Mathematics –**

| MP.2 | Reason abstractly and quantitatively. (MS-PS2-1),(MS-PS2-2),(MS-PS2-3) |
| 6.NS.C.5 | Understand that positive and negative numbers are used together to describe quantities having opposite directions or values; use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation. (MS-PS2-1) |
| 6.EE.A.2 | Write, read, and evaluate expressions in which letters stand for numbers. (MS-PS2-1),(MS-PS2-2) |
| 7.EE.B.3 | Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form, using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. (MS-PS2-1),(MS-PS2-2) |
| 7.EE.B.4 | Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. (MS-PS2-1),(MS-PS2-2) |
MS-PS3  Energy

Students who demonstrate understanding can:

MS-PS3-1. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object. [Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.]

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

MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.* [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.]

MS-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. [Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.]

MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. [Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] [Assessment Boundary: Assessment does not include calculations of energy.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*.

### Disciplinary Core Ideas

**PS3.A: Definitions of Energy**
- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. (MS-PS3-1)
- A system of objects may also contain stored (potential) energy, depending on their relative positions. (MS-PS3-2)
- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (MS-PS3-3),(MS-PS3-4)

**PS3.B: Conservation of Energy and Energy Transfer**
- When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5)
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. (MS-PS3-4)
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones. (MS-PS3-3)

**PS3.C: Relationship Between Energy and Forces**
- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. (MS-PS3-2)

**ETS1.A: Defining and Delimiting an Engineering Problem**
- More precisely a design task’s criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (Secondary to MS-PS3-2)

**ETS1.B: Developing Possible Solutions**
- A solution needs to be tested, and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. (Secondary to MS-PS3-2)

### Science and Engineering Practices

**Developing and Using Models**
- Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems.
- Develop a model to describe unobservable mechanisms. (MS-PS3-2)

**Planning and Carrying Out Investigations**
- Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. (MS-PS3-4)

**Analyzing and Interpreting Data**
- Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.
- Construct and interpret graphical displays of data to identify linear and nonlinear relationships. (MS-PS3-1)

**Constructing Explanations and Designing Solutions**
- Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.
- Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. (MS-PS3-3)

**Engaging in Argument from Evidence**
- Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed worlds.
- Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon. (MS-PS3-5)

### Crosscutting Concepts

**Scale, Proportion, and Quantity**
- Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. (MS-PS3-1),(MS-PS3-4)

**Systems and System Models**
- Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems. (MS-PS3-2)

**Energy and Matter**
- Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). (MS-PS3-5)
- The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS3-3)

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*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*

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**MS-PS3  Energy**

<table>
<thead>
<tr>
<th>ELA/Literacy –</th>
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<tbody>
<tr>
<td><strong>RST.6-8.1</strong></td>
<td>Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. <em>(MS-PS3-1),(MS-PS3-5)</em></td>
</tr>
<tr>
<td><strong>RST.6-8.3</strong></td>
<td>Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. <em>(MS-PS3-3),(MS-PS3-4)</em></td>
</tr>
<tr>
<td><strong>RST.6-8.7</strong></td>
<td>Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). <em>(MS-PS3-1)</em></td>
</tr>
<tr>
<td><strong>WHST.6-8.1</strong></td>
<td>Write arguments focused on discipline content. <em>(MS-PS3-5)</em></td>
</tr>
<tr>
<td><strong>WHST.6-8.7</strong></td>
<td>Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. <em>(MS-PS3-3),(MS-PS3-4)</em></td>
</tr>
<tr>
<td><strong>SL.8.5</strong></td>
<td>Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. <em>(MS-PS3-2)</em></td>
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<tr>
<th>Mathematics –</th>
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<tr>
<td><strong>MP.2</strong></td>
<td>Reason abstractly and quantitatively. <em>(MS-PS3-1),(MS-PS3-4),(MS-PS3-5)</em></td>
</tr>
<tr>
<td><strong>6.RP.A.1</strong></td>
<td>Understand the concept of ratio and use ratio language to describe a ratio relationship between two quantities. <em>(MS-PS3-1),(MS-PS3-5)</em></td>
</tr>
<tr>
<td><strong>6.RP.A.2</strong></td>
<td>Understand the concept of a unit rate a/b associated with a ratio a:b with b ≠ 0, and use rate language in the context of a ratio relationship. <em>(MS-PS3-1)</em></td>
</tr>
<tr>
<td><strong>7.RP.A.2</strong></td>
<td>Recognize and represent proportional relationships between quantities. <em>(MS-PS3-1),(MS-PS3-5)</em></td>
</tr>
<tr>
<td><strong>8.EE.A.1</strong></td>
<td>Know and apply the properties of integer exponents to generate equivalent numerical expressions. <em>(MS-PS3-1)</em></td>
</tr>
<tr>
<td><strong>8.EE.A.2</strong></td>
<td>Use square root and cube root symbols to represent solutions to equations of the form x² = p and x³ = p, where p is a positive rational number. Evaluate square roots of small perfect squares and cube roots of small perfect cubes. Know that √2 is irrational. <em>(MS-PS3-1)</em></td>
</tr>
<tr>
<td><strong>8.F.A.3</strong></td>
<td>Interpret the equation y = mx + b as defining a linear function, whose graph is a straight line; give examples of functions that are not linear. <em>(MS-PS3-1),(MS-PS3-5)</em></td>
</tr>
<tr>
<td><strong>6.SP.B.5</strong></td>
<td>Summarize numerical data sets in relation to their context. <em>(MS-PS3-4)</em></td>
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