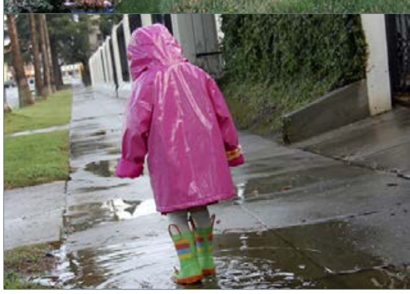
Grade Three

In many cases, grade three returns to some of the same disciplinary core ideas (DCIs) and phenomena as kindergarten but revisits them with a more sophisticated application of the science and engineering practices (SEPs). Table 4.1 shows a sequence of four possible phenomenon-based instructional segments in grade three. Instructional segment 1 revisits concepts of forces and motion that are nearly identical to kindergarten, but now it includes the added conceptual complexity of the effects of multiple forces. In kindergarten, it was sufficient for students to develop mental models (intuition), and now in grade three students learn tools for articulating those **models [SEP-2]** using diagrams of forces and motion. In IS2, students revisit their **argument [SEP-7]** from kindergarten that children look similar but not identical to their parents; but they now must document more detailed evidence by **analyzing and interpreting [SEP-4]** specific data. Instructional segment 3 helps students understand how the environment influences plants and animals, which is a mirror to the kindergarten concept that plants and animals can influence and modify their environment (California's Environmental Principles and Concepts [EP&Cs I, II]). Instructional segment 4 looks at weather patterns just like students did in kindergarten, but now it involves more **mathematical thinking [SEP-5]** in which students **analyze [SEP-4]** quantitative **measurements [CCC-3]** and adds a greater focus on the impacts of weather events on humans.

Patterns [CCC-1] and **cause and effect [CCC-2]** remain the key focus of grade three, with students using patterns as evidence that there must be a specific cause and effect relationship. The **explanations [SEP-6]** that students construct are still largely descriptions of what happened (evidence-based accounts), rather than descriptions of the invisible mechanisms that cause things to happen (which begins in grades four and five).

Table 4.1. Overview of Instructional Segments for Grade Three

	**1 Playground Forces** Students investigate the effects of forces on the motion of playground objects like balls and swings. They use pictorial models to describe multiple forces on objects and predict how they will move as those forces change. They ask questions about how electric and magnetic forces can act without touching and then use them to solve a problem in a design challenge.
	**2 Life cycle for Survival** Students observe life cycles as well as animals living in groups and then describe how these traits help organisms meet their needs. Students measure different traits to document the differences between offspring, their parents, and other members of their population. Some of these variations make organisms more likely to survive.
	**3 Surviving in Different Environments** Students develop a model of the relationship between traits, environment, and survival. Students collect evidence that organisms live in environments that best meet their needs and that changes in the environment can affect the traits and survival of organisms.
	**4 Weather Impacts** Students record patterns in weather over the school year and then analyze their data. They learn about weather patterns around the world and design solutions to reduce the impacts of weather hazards right in their own schoolyard.

Sources: epSos.de 2010; Mosdell 2012; U.S. Fish and Wildlife Service 2015; mintchipdesigns 2009

IS1

Grade Three Instructional Segment 1: Playground Forces

Children push and pull on objects every day, but they do not actively think about all these forces. Despite the fact that these forces are invisible, the human sense of touch is a built-in sensor for detecting them. In kindergarten, students investigated pushes and pulls and developed a simple model relating the direction and strength of pushes and pulls to the motion of objects. In grade three, they investigate a number of playground phenomena to extend this model to include many different forces acting on objects all at once. They apply the model to predict the motion of objects based on patterns of how they have moved in the past.

GRADE THREE INSTRUCTIONAL SEGMENT 1: PLAYGROUND FORCES

Guiding Questions

- What happens when several different forces push or pull an object at once?
- How can an object be pushed or pulled but not move?
- What do we need to know to predict the motion of objects?
- How can some objects push or pull one another without even touching?

Performance Expectations

Students who demonstrate understanding can do the following:

3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object. [Clarification Statement: Examples could include an unbalanced force on one side of a ball can make it start moving; and balanced forces pushing on a box from both sides will not produce any motion at all.] [*Assessment Boundary: Assessment is limited to one variable at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is limited to gravity being addressed as a force that pulls objects down.*]

3-PS2-2. Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion. [Clarification Statement: Examples of motion with a predictable pattern could include a child swinging in a swing, a ball rolling back and forth in a bowl, and two children on a see-saw.] [*Assessment Boundary: Assessment does not include technical terms such as period and frequency.*]

3-PS2-3. Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other. [Clarification Statement: Examples of an electric force could include the force on hair from an electrically charged balloon and the electrical forces between a charged rod and pieces of paper; examples of a magnetic force could include the force between two permanent magnets, the force between an electromagnet and steel paperclips, and the force exerted by one magnet versus the force exerted by two magnets. Examples of cause and effect relationships could include how the distance between objects affects strength of the force and how the orientation of magnets affects the direction of the magnetic force.] [*Assessment Boundary: Assessment is limited to forces produced by objects that can be manipulated by students, and electrical interactions are limited to static electricity.*]

3-PS2-4. Define a simple design problem that can be solved by applying ideas about magnets.* [Clarification Statement: Examples of problems could include constructing a latch to keep a door shut and creating a device to keep two moving objects from touching each other.]

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. [This performance expectation does not have a clarification statement or an assessment boundary.]

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. [This performance expectation does not have a clarification statement or an assessment boundary.]

GRADE THREE INSTRUCTIONAL SEGMENT 1: PLAYGROUND FORCES		
The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:		
Highlighted Science and Engineering Practices	**Highlighted Disciplinary Core Ideas**	**Highlighted Crosscutting Concepts**
[SEP-1] Asking Questions and Defining Problems [SEP-2] Developing and Using Models [SEP-3] Planning and Carrying Out Investigations [SEP-7] Engaging in Argument from Evidence	PS2.A: Forces and Motion PS2.B: Types of Interactions	[CCC-1] Patterns [CCC-2] Cause and Effect: Mechanism and Explanation [CCC-7] Stability and Change
CA CCSS Math Connections: 3.OA.1–7, MP 5, 6		
CA CCSS for ELA/Literacy Connections: RI.3.4; L.3.4, 5		
CA ELD Standards Connections: ELD.PI.3.1, 5, 12		

Students explore a variety of physical systems in which they can physically feel forces. They kick balls, hang from bars, push one another on the swing, slide down the slide, and land on the ground after leaping from a step on the play structure. Some forces are strong and some are weak. Some cause motion to start while others cause motion to stop. Sometimes, a person can feel multiple forces at the same time (e.g., riding a swing and feeling the seat push their bottom and their friend push their back). While students in kindergarten discussed how pushes and pulls have both strength and direction, this is the first time that the term *force* is explicitly used to describe them. To a physicist, pushes and pulls are both forces, they just act in different directions on an object. This instructional segment introduces students to four key ideas about forces: (1) every object has many forces acting on it at every moment; (2) forces add up, so that the overall effect depends not just on one of them, but on the combination of them; (3) when all the forces on an object equal or balance one another, there is no change in the motion, but the object will speed up, slow down, or change direction when the forces are unbalanced; and (4) some forces can act even when objects are not touching.

Grade Three Snapshot 4.1: Pictorial Models of Forces

Everyday phenomenon: Students feel a force as they kick a ball.

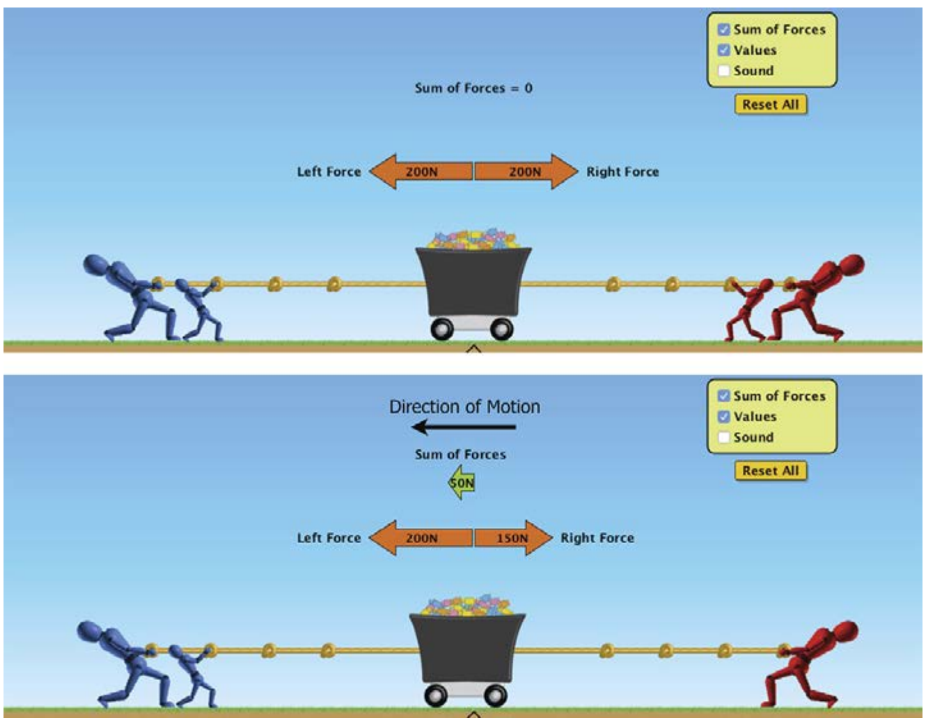
Ms. S took her students out to kick balls on the soccer field so that her students could feel the pressure of the ball against their feet. Did the ball move faster if they kicked it harder?

Investigative phenomenon: A ball sometimes rises off the ground when kicked.

For some students, the ball travelled straight across the ground, but for other kickers the ball rose off the ground and then fell back down. What was it that students were doing differently that caused the ball to fly up for some but not others? Is it just because they kicked the ball harder? Ms. S asked her students to draw two pictures side by side showing the path of the ball in each case. Then, she asked students to use a different arrow to represent the push of the kicker. They were making a **pictorial model [SEP-2]** of the force acting on the ball and its **effect [CCC-2]** on the ball's motion. In many cases, Ms. S's students drew the force arrow horizontally for both cases. Ms. S had students test out ways that they could get the ball to go higher in the air and then describe what they were doing. Eventually the students realized that the ball traveled along the ground when they pushed against the ball mostly horizontally, but when they got under the ball and pushed it slightly upward they could lift the ball in the air—the direction of the ball's motion depended on the direction of the push. They modified their drawings to reflect this change. Ms. S introduced the term *force* for the first time and had students label the arrow in their pictorial model with that word. Ms. S had her students draw pictorial models of forces many times during this instructional segment.

Students can **investigate [SEP-3]** specific situations that illustrate what happens when multiple forces act on an object at once (3-PS2-1). Students can push one another around in cardboard box race cars (see IS4 from kindergarten). What happens when two people push on the box together instead of just one? What happens when one person pushes the box forward while another student pushes it the opposite direction? How about if two people push it forward and only one pushes opposite? Or two people push forward and one person pushes sideways? By drawing **pictorial models [SEP-2]** of each situation, students can illustrate the effects of multiple forces acting on the same object at the same time. Other examples illustrate the same effects. Rather than kicking a ball on an open field, students push a ball against a wall. Can they still feel a force? Why doesn't the ball move? Two students can face one another, place their palms together, and then lean in towards one another. As they each push against one another, they can stay stationary as long as they balance one another with equal forces. If one person pulls away or pushes forward with more force, the system is no longer **stable [CCC-7]** and they move. In a game of tug-of-war, a flag attached to the rope might stay still even though both teams are pulling with strong forces on both sides (figure 4.1, top). But if one team lets go of the rope, the other team goes flying backwards when the force becomes unbalanced. Students can even experiment with a mini tug-of-war in which students pull at different angles on three or four strings attached together. Can they predict what which direction the system will move when one of the strings gets cut?

Figure 4.1. Balancing Forces in a Tug-of-War



Source: Adapted from PhET Interactive Simulations, University of Colorado Boulder (PhET) n.d.b.
Long description of Figure 4.1.

At this point, students should be able to use evidence from their **investigations [SEP-3]** and reasoning from their **model [SEP-2]** of forces to support two essential **claims [SEP-7]**:

- To start an object moving, you need to push or pull it with an unbalanced force.
- An object whose motion is not changing has no forces pushing or pulling it, or all the forces are balanced.

When students have a mental model that incorporates these claims, they can discover some invisible forces that push or pull that they may never have thought of as forces. When letting go of a ball or book, it begins to fall (i.e., start moving). This change in motion is evidence that a force must be acting. Gravity is the unseen force that acts on all objects at all times and causes the book to start moving. There is no way to escape gravity! Even if you travel far away from Earth in a spaceship, you will still always feel the pull of our planet (though it gets weaker as you get farther away). In grade five, students will collect evidence that gravity always acts downward on the surface of the Earth.

But what if a book just sits on a table and is not moving? Does gravity still pull on it? If so, why isn't it moving? A student can place their hand between a heavy book and the table in order to feel both the downward force of the book and the force of the table from below. Students should be able to draw a pictorial model of forces that shows the force of the table pushing upwards to balance out the force of gravity that pulls the book downward (figure 4.2). Students can feel a supporting force pushing their feet while they stand or pushing their bottom while they sit.

Figure 4.2. Student's Model of Balanced Forces Acting on a Book

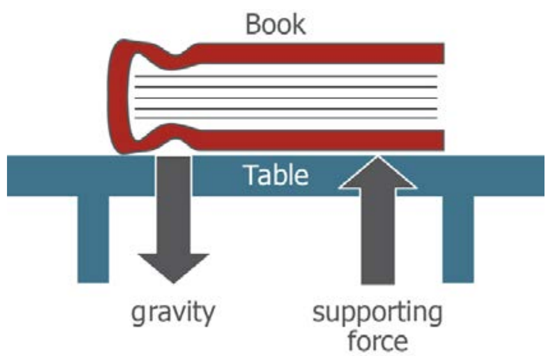


Diagram by M. d'Alessio
[Long description of Figure 4.2.]

Students can also use this model to identify another important invisible force, friction. When a student slides a book across a table, it eventually slows down and stops. A very common incorrect preconception is that the book runs out of energy or requires some sort of *motive* force to keep it in motion, but these ideas are not true. Any time an object slows down, that is evidence that there is a force pushing against the object that causes its motion to change. Students can experiment with the strength of the force of friction by trying to slide books or wooden blocks over a variety of surfaces with different amounts of friction. A book slows down quickly when the force of friction is strong and takes longer to slow down when friction is weak, even when the initial push that starts the motion is the same. Students can draw pictorial models showing different strength arrows representing friction for different surfaces. The force of friction always acts in the direction opposite the direction objects are moving, so it always slows them down. In the middle grades, students will build on this simple model of friction and relate it to energy transfer.

Opportunities for ELA/ELD Connections

During the instructional segment, provide age-appropriate definitions of domain-specific words and important academic vocabulary. In addition, select a few terms critical to understanding the concept. Have students use a graphic organizer so that they can gain a deeper understanding of these key concepts. One such organizer is the Frayer Model, which prompts students to write a definition, and allows for students to discuss specific characteristics of the word, examples, and nonexamples. Sample words for this topic could include *friction*, *gravity*, *forces*, *magnetic*, and *interactions*. Students should be given opportunities in class to practice using these words in context. An example is being given a force diagram and placing the words in their correct locations in the diagram.

CA CCSS for ELA/Literacy Standards: RI.3.4; L.3.4, 5

CA ELD Standards: ELD.PI.3.1, 12

Patterns in Motion

Knowing that every change in motion requires a force, students can now consider much more complicated motions on the playground. When a ball gets thrown upward, what force causes it to come down? In a game of handball, students throw the ball against the wall and it bounces back. How do forces on the ball change from one moment to the next during the game?

Observing motion on the schoolyard, students begin to notice that there are certain patterns in the way objects move. Balls that go up always come down. In a game of handball, students throw a ball against the wall and can predict where it will end up. A basketball reflecting off a backboard follows a similar pattern. A tetherball spirals downward at the end of a game as it slows down. Noticing the **pattern [CCC-1]** allows students to predict the motion of the object (3-PS2-2). The clarification statement for 3-PS2-2 indicates that the focus of this investigation should be on motion that repeats periodically, like the back-and-forth movement of a child on a swing. This specificity is not arbitrary—noticing the repeating patterns in motion is a key precursor to studying wave motion in fourth grade. Students will build on that experience with waves as they move toward the middle grades and high school to study the engineering application of waves in modern technology.

Ideally, students can **investigate [SEP-3]** **patterns [CCC-1]** of motion on a school swing set and use their observations to make and test predictions (3-PS2-2). If one is not available, small classroom pendulums (such as a small metal washer tied to the end of a string) are **physical models [SEP-2]**. What happens when they pull the swing back from different distances? Can they predict how far forward or how high the swing will travel based on how far back they pull the swing initially? By observing the length of time it takes to do two back and forth cycles, can they predict how long it will take the swing to complete four cycles? Can they identify a relationship between how far back they pull the swing and how long it takes to complete a back and forth cycle? If they do have access to both a swing set and a classroom pendulum, can they use patterns that they spot in the model to predict what will happen in the real swing? Students can attempt to identify the different forces acting in the swing system that **cause [CCC-2]** the repeated motion, but a complete explanation is not appropriate for grade-three levels of understanding. Students should be able to recognize that there are forces on the swinging person that cause it to change motion. Teachers can recognize that the force of gravity always pulls on the object in the same direction (downward) with the same force. The fact that the motion is constantly changing means that there must be another force that is changing. In this case, that force comes from the chain. Because the chain is always changing angles, it acts in different directions at different moments—sometimes pulling in a direction that reinforces gravity and sometimes pulling at an angle that works against it. Other cyclic patterns to investigate could be balls bouncing multiple times when dropped from different heights or a weight bouncing up and down when attached to a rubber band hanging from the monkey bars. Like the swing, these include gravity pulling down and a restoring force caused by a spring-like elastic material in both these cases.

Opportunities for Mathematics Connections

During the investigation on forces, students may need to measure and weigh different objects. Some students will need experience using the measurement tools. For example, students need to know that the scale should be balanced or zeroed out before beginning the measurement; to use a ruler, the end of the object being measured must line up at the zero mark on the ruler, etc.

CA CCSSM: 3.OA.1–7, MP 5, 6

Forces Without Touching

While students can feel when they apply a push or pull to an object that they touch, some forces do not require any contact at all. Gravity, electric force (*static electricity*), and magnetic force are all invisible forces, but they can change the motion of objects in exactly the same way as pushes or pulls between objects that touch.

Grade Three Snapshot 4.2: Probing Students' Initial Ideas on Forces

Ms. M's class has been discussing the forces between objects when they push or pull against one another, but to start the unit, she wanted to see what their initial ideas were about forces that do not require objects to be touching. She began, "Please take out your lab notebooks because I have a challenge question to probe your thinking. I am going to read you a story about two students and ask you to choose which one you agree with more. As scientists, I want you to **support your choice with evidence [SEP-7]** or examples from your experiences." Ms. M read the prompt and gave her students a few minutes to record their initial thinking in their notebooks.

Probe: Does It Have to Touch?

Two friends were arguing about forces. They disagreed about whether something had to be touched for a force to act. This is what they said:

Akiko: "I think two things have to touch in order to have a force between them."

Fern: "I don't think two things have to touch in order to have a force between them."

Which friend do you agree with most? Explain or draw a picture of your thinking. Provide examples that support your ideas about forces.

From Keeley and Harrington 2010

Ms. M continued, "Now turn to your thinking partner and share your choice and your thinking… Remember to listen respectfully to each other even if you do not agree. You can change your answer or add more evidence to your notebook entry if your thinking changes." She let the thinking partners share while she walked around the room listening to discussions and helping students to remain on task.

Everyday phenomena: Some objects move only when you touch them while others move without being touched.

After ten minutes of animated discussion, Miss M returned to the front of the class, "So, let's see where we are as a group. When I say GO, you'll put one finger up if you agree most with Akiko and two fingers up if you agree most with Fern. Ready, set GO!" The group was evenly split.

She prompted students to find a partner who disagreed with them. After a few minutes of discussion, Ms. M initiated a whole-class discussion and recorded student ideas on the board. Supporters of Akiko's position pointed out evidence like "A soccer ball won't move unless I kick it" and "My book has to touch the table to have the table push on it." Supporters of Fern's position pointed out other evidence. Clara said "If I push a ball up in the air, it is going up but then it will fall down. Nothing is touching it, but it moves down. There's gravity even though the ball isn't touching the Earth." Aisha also explained excitedly, "Magnets push and pull even when they don't touch objects. My grandma has a magnet that I can use to make a paperclip move on top of the kitchen table by moving

Grade Three Snapshot 4.2: Probing Students' Initial Ideas on Forces

the magnet around **below** the table. It's like magic."

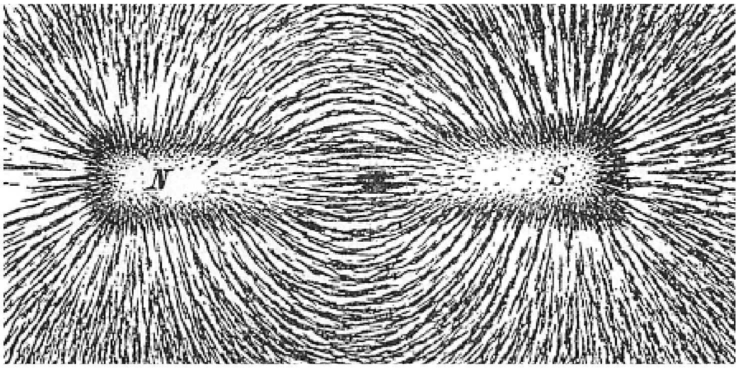
Ms. M then used her students' initial ideas to identify and introduce forces that can act without touching. She told students, "In the next weeks we will be learning more about interactions such as gravity, magnetism, and static electricity. At the end you will be able to explain how Aisha can magically move the paperclip with her grandmother's magnet."

Resources:

Keeley, Page, and Rand Harrington. 2010. *Uncovering Student Ideas in Physical Science: 45 New Force and Motion Assessment Probes.* Arlington: National Science Teachers Association.

Electric fields are easy to visualize with scraps of paper attracted to a charged balloon (rubbed against someone's hair), but the changes from static electricity are so small that it is hard to physically feel the force. Magnets, however, can be strong enough that students can physically feel their motion. When students have the opportunity to freely explore with different magnets and magnetic objects, they come up with all sorts of **questions [SEP-1]** about how they work. Teachers can help students focus on a few questions that could be investigated in the classroom about **cause and effect relationships [CCC-2]** (3-PS2-3). Questions might include the following: How do magnets affect different types of objects? How does the magnet's orientation change the magnet's effect on other magnets or objects? How does the distance between the magnet and the object affect the strength of the magnetic force? By sprinkling iron filings in a flat, sealable plastic container (for protection from getting into eyes, nose, or mouth) and holding the container above a magnet, students can ask questions about how the position of the magnet affects the pattern that the iron filings make (figure 4.3). In each of these example questions, the question includes a reference to both a cause and an effect. A question such as, What happens if I put three magnets together? is a great example of curiosity but it does not include any specific statement about the effect. After a student has the chance to try out this interesting question, the teacher can help the student ask the next level of question that includes both the cause and effect, such as, How does the number of magnets affect the strength of the magnetic force? Scientists often begin with open-ended curiosity-based questions but then need to convert those into questions that will later be used to design scientific investigations. Narrowing down both a cause and an effect will help determine what types of observations to collect, how to collect them, and what sort of data or measurements will be necessary to answer the question. Performance expectation 3-PS2-3 does not actually require that students perform any investigations or answer their questions, but students will probably want to anyway.

Figure 4.3. Iron Fillings in a Flat, Sealable Plastic Container



Source: Black and Davis 1913, 242, fig. 200
Long description of Figure 4.3.

Engineering Connection: Designing a Better Swing

Scientific discoveries about the natural world can often lead to new and improved technologies, which are developed through the engineering design process. Some engineers design recreational equipment such as playground equipment. This engineering connection asks students to use magnets to make a "better" swing. This is one possible challenge in which students define a problem that could be solved by magnets (3-PS2-4). The emphasis in this performance expectation is on **defining the problem [SEP-1]**, which requires students to identify constraints and define the criteria for success (3–5-ETS1-1). Students can also generate multiple solutions and compare them (3–5-ETS1-2).

Prompt for students:
What if you could have a swing that made you go fast and high without any pushing or pulling by you or your friends? Can you figure out a way to use your understanding of magnets to design a swing that uses magnetic force to keep the swing moving? First, you need to figure out the requirements such as how big a person could ride the swing, how much space you have available on the playground for this new toy, and how many magnets you can use. Then, you'll need to decide how you will know if you have succeeded. Is it enough for the swing to go back and forth once? Or does it need to keep going multiple times? How many? How high does it need to go in order to be fun enough? Sketch two different designs in your notebook. What are the relative advantages and disadvantages of each?

Materials for each group: a 2-foot length of string, two ring or disc magnets, one binder clip, one classroom chair.

Source: Based on Egg Harbor Township STEM Committee. 2013. 3rd Grade Motion and Stability Unit. https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link1

Sample Integration of Science and ELD Standards in the Classroom

Students have experimented with magnets and observed videos of various inventions that use magnets and electricity. They listen to a teacher read aloud from an informational text about cause and effect relationships of electrical and magnetic interactions between two objects and how inventors design solutions to problems by using these scientific principles (3-PS2-3, 3-PS2-4). At strategic points during the teacher read-aloud, students discuss, in pairs, open-ended, detailed questions designed to promote extended discourse (e.g., In what ways does a magnet affect a compass? How do we know? What changes would you make to X design to make it better?). The students have an opportunity to practice their response before sharing out to the class. The teacher supports the comprehension of students at the Emerging level of English proficiency by using diagrams labeled in both English and the students' home language to support the ideas in the text and by attending to the meanings of general academic terms (in addition to science-specific terms). Before reading, the teacher also makes sure to show short videos related to the topic in the two primary home languages of students in the classroom: English and Spanish.

CA ELD Standards: ELD.PI.3.5

Source: Lagunoff et al. 2015, 252–253