Unit Summary

What happens if you push or pull an object harder?

During this unit of study, students apply an understanding of the effects of different strengths or different directions of pushes and pulls on the motion of an object to analyze a design solution. The crosscutting concept of *cause and effect* is called out as the organizing concept for this disciplinary core idea. Students are expected to demonstrate grade-appropriate proficiency in *planning and carrying out investigations* and *analyzing and interpreting data*. Students are also expected to use these practices to demonstrate understanding of the core ideas.

This unit is based on K-PS2-1, K-PS2-2, and K-2 ETS1-3.

Student Learning Objectives

Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. *[Clarification Statement: Examples of pushes or pulls could include a string attached to an object being pulled, a person pushing an object, a person stopping a rolling ball, and two objects colliding and pushing on each other.] [Assessment Boundary: Assessment is limited to different relative strengths or different directions, but not both at the same time. Assessment does not include non-contact pushes or pulls such as those produced by magnets.]* **(K-PS2-1)**

Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull. *[Clarification Statement: Examples of problems requiring a solution could include having a marble or other object move a certain distance, follow a particular path, and knock down other objects. Examples of solutions could include tools such as a ramp to increase the speed of the object and a structure that would cause an object such as a marble or ball to turn.] [Assessment Boundary: Assessment does not include friction as a mechanism for change in speed.]* **(K-PS2-2)**

Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs. (K-2-ETS1-3)

Quick Links

Unit Sequence	
Part A: *Why do scientists like to play soccer?*	
Concepts	**Formative Assessment**
• People use different ways to study the world. • Simple tests can be designed to gather evidence to support or refute student ideas about causes. • Pushes and pulls can have different strengths and directions. • Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. • When objects touch or collide, they push on one another and can change motion. • A bigger push or pull makes things speed up or slow down more quickly.	*Students who understand the concepts are able to:* • With guidance, design simple tests to gather evidence to support or refute ideas about cause-and-effect relationships. • With guidance, plan and conduct an investigation in collaboration with peers. • With guidance, collaboratively plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. *(Assessment is limited to different relative strengths or different directions, but not both at the same time. Assessment does not include noncontact pushes or pulls such as those produced by magnets.)* Some examples of pushes and pulls on the motion of an object could include: ✓ A string attached to an object being pulled. ✓ A person pushing an object. ✓ A person stopping a rolling ball. ✓ Two objects colliding and pushing on each other.

Unit Sequence	
Part B: *How can you design a simple way to change the speed or direction of an object using a push or pull from another object?*	
Concepts	**Formative Assessment**
• Simple tests can be designed to gather evidence to support or refute student ideas about causes. • Pushes and pulls can have different strengths and directions. • Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. • A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions.	*Students who understand the concepts are able to:* • With guidance, design simple tests to gather evidence to support or refute ideas about cause-and-effect relationships. • Analyze data from tests of an object or tool to determine if it works as intended. • Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.

• Because there is always more than one possible solution to a problem, it is useful to compare and test designs.	• Analyze data to determine whether a design solution works as intended to change the speed or direction of an object with a push or a pull. • Examples of problems requiring a solution could include having a marble or other object move a certain distance, follow a particular path, and knock down other objects. • Examples of solutions could include tools such as a ramp to increase the speed of the object and a structure that would cause an object such as a marble or ball to turn. *(Assessment does not include friction as a mechanism for change in speed.)*

What It Looks Like in the Classroom

In this unit of study, students plan and carry out investigations in order to understand the effects of different strengths and different directions of pushes and pulls on the motion of an object. Students will also engage in a portion of the ***engineering design process*** to determine whether a design solution works as intended to change the speed or direction of an object.

Scientists often design simple tests in order to gather evidence that can be used to understand cause-and-effect relationships. In this unit's progression of learning, kindergarteners need adult guidance to collaboratively plan and conduct simple investigations to discover and compare the effects of pushes and pulls on the motion of an object. Students will need opportunities to push and pull a variety of objects, such as balls, toy cars, pull toys, cans, tops, and boxes. Students should push/pull these objects first with varying strengths, and then in a variety of directions. They should also explore the effects of pushing objects into one another, as well as into walls and other stationary objects. Students should record their observations using pictures and words, and should participate in class discussions on the effects of varying the strength or direction of a push or pull on an object.

As students engage in these types of simple force and motion investigations, they will learn that:

- ✓ Pushes and pulls can have different strengths and directions.
- ✓ Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.
- ✓ When objects touch or collide, the object's motion can be changed.
- ✓ The force of the push or pull will make things speed up or slow down more quickly.

To enhance students' experiences, teachers can schedule time for students to investigate these force and motion concepts using playground equipment, such as swings, seesaws, and slides. Teachers can also use trade books and multimedia resources to enrich students' understanding. As students participate in discussions, they should be encouraged to ask questions, share observations, and describe cause-and-effect relationships between forces (pushes and pulls) and the motion of objects.

As students come to understand the force and motion concepts outlined above, they should engage in the ***engineering design process*** as follows.

- Students are challenged to design a simple way to change the speed or direction of an object using a push or pull from another object.
- As a class, students determine what the design should be able to do (criteria). For example:

- ✓ An object should move a second object a certain distance;
- ✓ An object should move a second object so that the second object follows a particular path;
- ✓ An object should change the direction of the motion of a second object; and/or
- ✓ An object should knock down other specified objects.

- Students determine the objects that will move/be moved (balls, ramps, blocks, poker chips) and the types of structures (ramps or barriers) and materials (rubber bands, paper tubes, cardboard, foam, wooden blocks) that can be used to meet this challenge.
- Groups of students then develop a simple drawing or diagram and use given materials to build their design. Groups should be given a predetermined amount of time to draw and build their designs.
- Groups share their designs with the class, using their drawings or diagrams, and then test their designs.
- Students make and use observations to determine which of the designs worked as intended, based on the criteria determined by the class.

While engaging in this process, students should use evidence from their observations to describe how forces (pushes and pulls) cause changes in the speed or direction of an object.

In this unit of study, students learn that problem situations can be solved through engineering, and that because there is always more than one possible solution to a problem, it is useful to compare and test designs. Students will use what they have learned about the effect of pushes and pulls of varying strength and direction on the motion of an object to determine whether a design solution works as intended. This process is outlined in greater detail in the previous section.

Connecting with English Language Arts/literacy and Mathematics

English Language Arts

In order to integrate English Language Arts into this unit, students need the opportunity to participate in shared research that will enhance their understanding of the effect of forces (pushes and pulls) on objects. This could include exploring simple books and other media or digital resources. With prompting and support, students should ask and answer questions about key details in texts in order to seek help, get information, or clarify something that they do not understand. With support from adults, students will also recall information from experiences to answer questions and clarify their thinking. With support and/or collaboration, they can use digital tools to produce and publish simple informative writing or to document their observations of the simple force and motion systems they design and build.

Mathematics

During this unit of study, students will make connections to Mathematics in a number of ways. Kindergartners can use simple nonstandard units to measure the distances that two different objects travel when pushed or pulled or the distances that an object travels when varying the strength of a push or a pull. If using two objects, students can compare them using a measurable attribute, such as weight, to see which object has “more of” or “less of” the attribute, and describe the effect that increased weight has on the distance that an object travels. As students conduct multiple trials with the two objects (or with a single object, varying the strength of the push or pull), they can document the distance traveled in a simple graph. Then they can analyze the data in order to describe the cause-and-effect relationship between forces and motion of objects. As students collect and analyze data, they are learning to reason abstractly and quantitatively and use appropriate tools strategically.

Modifications
(Note: Teachers identify the modifications that they will use in the unit. See NGSS Appendix D: All Standards, All Students/Case Studies for vignettes and explanations of the modifications.) • Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community. • Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling). • Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies). • Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences). • Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings. • Use project-based science learning to connect science with observable phenomena. • Structure the learning around explaining or solving a social or community-based issue. • Provide ELL students with multiple literacy strategies. • Collaborate with after-school programs or clubs to extend learning opportunities. • Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA).

Research on Student Learning
Students tend to think of force as a property of an object ("an object has force," or "force is within an object") rather than as a relation between objects. In addition, students tend to distinguish between active objects and those objects that support or block or otherwise act passively. Students tend to call the active actions "force" but do not consider passive actions as "forces" (NSDL, 2015).

Future Learning
Grade 3 Unit 2: Forces and Motion • Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. *(Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.)*

- The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.)
- Each force acts on one particular object and has both strength and direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative, addition of forces is used at this level.)
- The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.)
- Objects in contact exert forces on each other.
- Electric and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other.

Grade 4 Unit 5: Transfer of Energy

- Energy can be moved from place to place by moving objects or through sound, light, or electric currents.

Connections to Other Units
N/A

Sample of Open Education Resources
Push Pull-Changing Direction: Students investigate the interactions between colliding objects using pushes and pulls. Students play a game of kickball and observe how the ball is pushed, pulled, started, stopped, or collided with other objects and how it changed position and speed. As a group, students will then brainstorm about other objects being pushed, pulled or colliding and then choose one of those objects to investigate.
Marble Roll: This is an assessment probe from the book Uncovering Student Ideas in Primary Science Vol. 1 that is used to elicit children's descriptions of motion. The probe is designed to reveal how students describe the path of a moving object as it leaves a winding track.
Roller Coaster: There are two parts to this lesson from the book More Picture Perfect Science Lessons. In the first part learners explore ways to change the speed and direction of a rolling object by building roller coasters out of pipe insulation after reading the book, Roller Coaster by Marla Frazee. In the second part students read I Fall Down by Vicki Cobb and then investigate the idea that gravity affects all objects equally by conducting dropping races with everyday items.
Ramps 2: Ramp Builder: This is a multi-day lesson plan that has students design, build, and test their own ramps. Students are introduced to a variety of materials and explore putting them together. Students engage in an inquiry-based learning experience to reinforce math, science, and technology. They create plans for ramps by evaluating a variety of materials provided to them.

Teacher Professional Learning Resources

NSTA Web Seminar: Teaching NGSS in Elementary School—Kindergarten

The seminar was led by expert teachers Carla Zembal-Saul, Professor of Science Education, Penn State University; Mary Starr, Executive Director, Michigan Mathematics and Science Centers Network; and Kathy Renfrew, K-5 Science Coordinator, VT Agency of Education. Carla, Mary and Kathy engaged with participants to gauge their familiarity with *NGSS* for kindergarten, and provided a number of example activities and videos on how to implement it, e.g., different approaches to teaching weather and climate core ideas. The web seminar was then wrapped up by Ted Willard, who suggested a number of resources and events for participants to further develop their understanding of *NGSS* for kindergarten, as well as other grade levels.

View the resource collection.

Continue discussing this topic in the community forums.

NSTA Web Seminar: Teaching NGSS in K-5: Constructing Explanations from Evidence

Carla Zembal-Saul, Mary Starr, and Kathy Renfrew, provided an overview of the *NGSS* for K-5th grade. The web seminar focused on the three dimensional learning of the *NGSS*, while introducing CLAIMS-EVIDENCE-REASONING (CER) as a framework for introducing explanations from evidence. The presenters highlighted and discussed the importance of engaging learners with phenomena, and included a demonstration on using a KLEWS chart to map the development of scientific explanations of those phenomena.

To view related resources, visit the resource collection.

Continue discussing this topic in the community forums.

NSTA Web Seminar: Motion and Stability: Forces and Interactions

The presenters were Alicia Alonzo from Michigan State University and Alex Robinson, a teacher at Thornapple Kellogg High School in Middleville, Michigan. This was the fourth web seminar in a series focused on the disciplinary core ideas that are part of the *Next Generation Science Standards (NGSS)*. The program featured strategies for teaching about physical science concepts that answer questions such as "How can one explain and predict interactions between objects and within systems of objects?"

Dr. Alonzo began the presentation by providing an overview of how disciplinary core ideas fit into the overall structure of *NGSS*. Then she and Mr. Robinson discussed common student preconceptions related to Motion and Stability: Forces and Interactions. They also showed how this disciplinary core idea progresses across grade bands. Participants had the opportunity to ask questions and discuss ideas for classroom application with other participating teachers.

View the resource collection.

Continue discussing this topic in the community forums.

Appendix A: NGSS and Foundations for the Unit

Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. *[Clarification Statement: Examples of pushes or pulls could include a string attached to an object being pulled, a person pushing an object, a person stopping a rolling ball, and two objects colliding and pushing on each other.]* [Assessment Boundary: Assessment is limited to different relative strengths or different directions, but not both at the same time. Assessment does not include non-contact pushes or pulls such as those produced by magnets.*]* **(K-PS2-1)**

Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull. *[Clarification Statement: Examples of problems requiring a solution could include having a marble or other object move a certain distance, follow a particular path, and knock down other objects. Examples of solutions could include tools such as a ramp to increase the speed of the object and a structure that would cause an object such as a marble or ball to turn.]* [Assessment Boundary: Assessment does not include friction as a mechanism for change in speed.*]* **(K-PS2-2)**

Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool. (K-2-ETS1-1)

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

Science and Engineering Practices

Planning and Carrying Out Investigations

- With guidance, plan and conduct an investigation in collaboration with peers. (K-PS2-1)

Analyzing and Interpreting Data

- Analyze data from tests of an object or tool to determine if it works as intended. (K-PS2-2)

Asking Questions and Defining Problems

- Ask questions based on observations to find more information about the natural and/or designed world(s). (K-2-ETS1-1)
- Define a simple problem that can be solved through the development of a new or improved object or tool. (K-2-ETS1-1)

Developing and Using Models

- Develop a simple model based on evidence to represent a proposed object or tool. (K-2-ETS1-2)

Disciplinary Core Ideas

PS2.A: Forces and Motion

- Pushes and pulls can have different strengths and directions. (K-PS2-1), (K-PS2-2)
- Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. (K-PS2-1), (K-PS2-2)

PS2.B: Types of Interactions

- When objects touch or collide, they push on one another and can change motion. (K-PS2-1)

PS3.C: Relationship Between Energy and Forces

- A bigger push or pull makes things speed up or slow down more quickly. *(secondary to K-PS2-1)*

ETS1.A: Defining Engineering Problems

- A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. *(secondary to K-PS2-2)*

Crosscutting Concepts

Cause and Effect

- Simple tests can be designed to gather evidence to support or refute student ideas about causes. (K-PS2-1), (K-PS2-2)

Structure and Function

- The shape and stability of structures of natural and designed objects are related to their function(s). (K-2-ETS1-1)

Connections to the Nature of Science

Scientific Investigations Use a Variety of Methods

- Scientists use different ways to study the world. (K-PS2-1)

	ETS1.A: Defining and Delimiting Engineering Problems • A situation that people want to change or create can be approached as a problem to be solved through engineering. (K-2-ETS1-1) • Asking questions, making observations, and gathering information are helpful in thinking about problems. (K-2-ETS1-1) • Before beginning to design a solution, it is important to clearly understand the problem. (K-2-ETS1-1)	

English Language Arts	Mathematics
With prompting and support, ask and answer questions about key details in a text. (K-PS2-2) **RI.K.1** Participate in shared research and writing projects (e.g., explore a number of books by a favorite author and express opinions about them). (K-PS2-1) **W.K.7** Ask and answer questions in order to seek help, get information, or clarify something that is not understood. (K-PS2-2) **SL.K.3**	Reason abstractly and quantitatively. (K-PS2-1), (K-2-ETS1-1),(K-2-ETS1-3) **MP.2** Model with mathematics. (K-2-ETS1-1), (K-2-ETS1-3) **MP.4** Use appropriate tools strategically. (K-2-ETS1-1), (K-2-ETS1-3) **MP.5** Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object. (K-PS2-1) **K.MD.A.1** Directly compare two objects with a measurable attribute in common, to see which object has “more of”/”less of” the attribute, and describe the difference. (K-PS2-1) **K.MD.A.2**