# HOW DOES FORCE AFFECT MOTION?

## Fighting children's misconceptions with the "fantastic-four" ways in which force affects motion

*By Gerald Darling*

Whether playing soccer at recess, walking to lunch, or sitting at their desk, children encounter forces every moment of their lives. The connection between force and motion is absolutely amazing to children, so anyone working with them better be prepared for the battery of tough questions they ask: "What made the ball move that way? Why does a soccer ball eventually stop if no one touches it? Why is it so hard to walk on an icy sidewalk? What happens to gravity when a book is sitting on the desk?" In their enthusiasm to discover answers to these questions, many students develop misconceptions which make the topic of force difficult to teach. I start with a preassessment survey to identify misconceptions and determine student understanding of forces. Then I engage students with hands-on activities in an active learning environment to address student misconceptions and develop their knowledge of forces. As a result of participating in these activities, students will be able to explain what a force is using common, everyday examples, identify the four ways in which a force can change the motion of an object, describe the force of friction using common examples, and identify the forces acting on an object at rest. These activities were developed for students in fourth grade and address *A Framework for K–12 Science Education* (NRC 2011) as force is one of the core ideas for physical science.

## Identifying Misconceptions

A major reason why the connection between force and motion is so hard for students to understand lies in the misconceptions that students bring into the classroom. One of the most challenging (and most important) responsibilities of a teacher is to identify what students know, what they don't know, and what misconceptions they may have. To accomplish this for the topic of force and motion, I have developed a preassessment survey, as shown in Figure 1. This survey consists of a series of questions that probe student understanding of three important areas. The first question examines student thinking concerning how a force can change the motion of an object. The next two questions investigate student thinking about common, everyday forces we all deal with—friction and gravity. In the preassessment survey, students are asked to explain their thinking in descriptive, complete sentences. Some teachers may want to modify the preassessment survey to allow students to draw out their thinking with diagrams, which is another excellent way to determine what students know, what they don't know, and what misconceptions they may have.

## What Can a Force Do?

From their everyday experiences of pushing a toy car across the floor or pulling a car door closed, children are familiar with force as a push or pull. Misconceptions develop concerning how forces affect motion. From the results of the preassessment survey (see Figure 1, question 1), many students know that a force can cause an object to move. A typical example a student gives on the preassessment is "kicking the ball during a game of soccer moves the ball," but most students who give this example will not circle change in speed or change in direction, which both also occur to the ball (many times!) in every game of soccer.

I take students outside to explore the connection between force and motion with hands-on activities using a tennis ball and soccer ball. By the end of the activity, they will discover what I call the "fantastic-four" ways in which a force can change the motion of an object. We start by making a circle and taking turns carefully tossing the tennis ball around the circle. When the ball comes to each student, I ask them to hold it still and then carefully toss the ball with a small force to their neighbor. After a few times around, I ask, "What's the force of your toss doing?" A typical student response is "It pushes the ball and makes it move." The ball was at rest, but the force of the toss changes the ball's speed and causes it to move. That's two of the fantastic-four of forces: A force can change an object's speed and make an object move. By carefully experimenting with stronger tosses, they can vocalize that the more forceful the toss, the larger the ball's change in speed. A little toss produces a little change in speed, but a larger toss produces a larger change in speed.

We continue to toss the tennis ball around the circle, but this time I ask them to think about the catch rather than the toss. I ask them, "What is your hand doing to the ball during the catch? Is there a push or a pull? How has the ball's motion changed?" Students will respond: "My hand pulls the ball in, stopping it." The ball was moving, but the force of the catch changes the tennis ball's speed and causes the ball to stop. Once again, the force changes the ball's speed, but we have discovered that a force can stop an object; this is the third of our fantastic-four of forces. So, a force is a push or pull that can cause an object to move, stop, or change speed.

Next, we toss the soccer ball around the circle. I ask them to compare how much force it takes to toss the soccer ball to their neighbor, compared to how much force it takes to toss the tennis ball to their neighbor. After a few times around, they recognize that the amount of force needed to move an object is related to the object's mass. Students will respond: "The soccer ball's bigger and takes a bigger force to move it" to their neighbor. They recognize that the tennis ball, with less mass, is easier to move.

To determine the fourth of the fantastic-four of forces, students make a large circle and take turns carefully kicking the soccer ball with a small force to their neighbor. I ask that when the ball comes to each student, they don't

**Figure 1.**

### Preassessment survey

Directions for Question 1: Circle all of the ways a force can change the motion of an object. Use a descriptive, complete sentence to give an example of each way that you circle.

(1) A force can cause an object to:

move

stop

change speed

change direction

Examples: ____________________

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Directions for Questions 2 and 3: Read each of the following statements carefully. Circle whether you agree or disagree with each statement, and then explain your thinking in a descriptive, complete sentence.

(2) After you kick a ball in a straight line on the soccer field, there is a force that keeps the ball moving.

Agree or Disagree

Explain: ____________________

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(3) A book sitting at rest on the desk has forces acting on it.

Agree or Disagree

Explain: ____________________

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stop it but carefully pass it soccer-style to their neighbor. Students quickly recognize the last way that a force can change the motion of an object: Forces can change the direction of an object. So a force is a push or a pull that can cause an object to move, stop, change speed, or change direction—the fantastic-four of forces. I end this lesson by asking each student to write a complete sentence giving an example of each of the four ways in which a force can change the motion of an object.

## The Force of Friction

On the preassessment survey (see Figure 1, question 2), students overwhelmingly agree with the following statement: "After you kick a ball in a straight line on the soccer field, there is a force that keeps the ball moving." Most elementary students have the misconception that if an object is in motion, a force is acting to keep the object moving (Ioannides and Vosniadou 2002). Typical student explanations include: "The ball has a force moving it," and "The ball has a force inside that keeps it going." When asked why the ball eventually stops, students think this force has been consumed: "When the force is all gone, the ball stops."

To clear up this misconception, I ask students to take turns kicking a soccer ball in a straight line on a grassy soccer field, carefully observing the results. The ball was at rest, but the force of their kick changes the ball's speed and causes the ball to move. That's two of the fantastic-four of forces. Then I ask the students, "What happens to the motion of the ball after you kick it?" Students respond, "The ball slows down and stops." At this point several students will excitedly point out that a change in the ball's speed and stopping are also two of the fantastic-four of forces! Students recognize that there is not a force that keeps the ball moving, but actually a force that slows the ball down and stops it. I tell them the name of this force is friction, and it occurs whenever one surface tries to move past another. I explain that as the ball moves through the grass, the grass pulls on the ball slowing it down; friction always acts to oppose motion.


PHOTOGRAPHS COURTESY OF THE AUTHOR

Pulling as hard as he can, this student cannot overcome the force of friction!

To explore friction between different surfaces, I ask: "If you kick the ball with the same force, will it go farther on the grassy field or the blacktop?" Each student gets to try this investigation, and they all come to the same conclusion: The ball will travel farther on the blacktop. I ask them why the blacktop has a smaller pull on the ball, allowing it to travel farther. Students will correctly say: "The blacktop is much flatter and smoother, so the ball goes over it more easily." When we return to the classroom, I ask each student to extend their knowledge of friction and write a complete sentence to answer the question, "Why is it so hard to walk on an icy sidewalk (what force is involved and how big is it)?" A typical student response is, "The ice is smooth, so the pull of friction small, and things slide over it easily."

To demonstrate how strong the force of friction can be, I use an activity developed by the Mythbusters TV series, called "Phone Book Friction" (Discovery 2008). Students take turns trying to pull apart two interleafed phone books. They are astonished when they, or the strongest child in the class, cannot pull the books apart. I finish this lesson on friction by showing an amazing and educational three-minute clip from the Mythbusters show (see Internet Resource). This clip shows the incredible lengths to which the Mythbusters cast (always a favorite with elementary students) go in trying to pull two interleaved phone books apart.

## Balancing the Force of Gravity

Elementary students are a delight to teach because they are very curious about the everyday workings of our universe. For example, I tell the students something remarkable happens when they hold their book out at arm's length and simply release it—the book doesn't stay where they left it! It was at rest, but then it moves. What's responsible for this stunning motion? After our discussion of the fantastic-four of forces, students realize that a force is pulling on the book, which changes its speed and moves it. But this is no ordinary force: It can make the book move without being in direct contact with it! Many children are familiar with gravity and correctly describe it as "the force the Earth pulls us down with when we jump."

Misconceptions develop when gravity acts on an object at rest. On the preassessment survey (see Figure 1, question 3), many students will disagree with the statement: "A book sitting at rest on the desk has forces acting on it." Students equate force with moving an object and will explain, "The book is at rest, so there are no forces on it."

To clear up this misconception, I ask the students to conduct a simple investigation. Drop a book on their desk. Gravity is pulling the book down, but what does the desk do? When asked, students will respond, "The desk gets in the way and stops the book." After our discussion of

The force of gravity continuously pulls the jumping child back to the ground.

## Connecting to the Standards

This article relates to the following National Science Education Standards (NRC 1996):

### Content Standards

#### Grades K –4

Standard B: Physical Science

- Position and motion of objects

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academies Press.

the fantastic-four of forces, students recognize the desk is changing the book's speed and stops it; the desk is applying a force on the book, pushing it up! So objects at rest on a flat surface, like a book on a desk or a ball on the ground, have the downward pull of gravity balanced by upward push of the surface they are resting on.

Students are now prepared to write a sentence answering the question: "What happens to gravity when a book is sitting on the desk (i.e., what forces are involved, and how big are they)?" A typical student response is, "Gravity is balanced by the desk pushing up." Some teachers may want to make use of before and after journaling as another method of displaying student growth on these topics.

## May The Forces Be With You, and Newton, Too!

The connection between force and motion forms the foundation of physical science. The activities presented in this article not only address student misconceptions but also develop students' knowledge of forces and prepare them to analyze new forces they encounter. Later in fourth grade, students will identify the electric force that pushes and pulls electric charges, producing electric current. After electricity, students will encounter magnetism. Magnets, with their opposite poles pulling (attracting) each other, and their like poles pushing (repelling) one another, astonish children. Students will clearly recognize a force at work, since all of the fantastic-four of forces—pushes or pulls that cause an object to move, stop, change speed, or change direction—are present.

Some elementary students will recognize that moving or stopping are specific examples of a change in an object's speed. In middle school, students learn that speed is part of a more complex physical quantity called velocity, which includes both the speed and the direction of motion. When a force causes an object to move, stop, change speed, or change direction, the force is causing a change in the object's velocity. In high school physics classes, students learn that a change in an object's velocity is called acceleration. Thus a force causes an object to accelerate. This is Newton's second law of motion: The net force applied to an object is equal to the object's mass multiplied by the object's acceleration. Students will continue their study of forces in middle and high school, and with the foundation that these activities give students, I tell them "the forces will be with you, and Newton, too!" ■

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## References

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## Resources

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## Internet Resource

Mythbusters: Phone Book Friction *www.dsc.discovery.com/tv-shows/mythbusters/videos/phone-book-friction.htm*

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