Fun With Forces and Motion

Using simple materials to set up a game where elementary students can learn about force and motion by observing their interactions with different objects

By Dennis Rosemartin

When I first started teaching fourth-grade science, I remember thinking that some concepts were abstract and difficult to teach. I hear the same concerns among many preservice teachers in my elementary science methods course. What I eventually learned as a teacher—and now teach my students—is that children are already constructing their understanding of science concepts such as forces and motion in their daily activities and games. In this article, I describe a lesson that I teach to preservice teachers and which they have taught to third-grade students. I designed the lesson to incorporate the natural curiosities that emerge through play as a way to engage students in discussions and scientific evaluations of what causes objects to move certain ways. It was developed to focus on the Next Generation Science Standard (NGSS) for third-grade physical science (3-PS2), Motion and Stability: Forces and Interactions (NGSS Lead States 2013). This lesson is taught during a 75-minute college class period. I model each phase and include the reasoning behind the activities. I also highlight moments when students engage in the activity in a way that their elementary students would. I use the 5E instructional model (Engage, Explore, Explain, Elaborate, and Evaluate) to teach this lesson.

Engage

Creating a relatable entry point to the science concept being taught is important. Science Talks (Gallas 1995) accomplish this and help set up the essential questions for the investigation part of the lesson. These talks are intentional discussions that “occur in a separate and formally prescribed time frame” (Gallas 1995, p. 1). The teacher facilitates them, and they build anticipation for the main part of the lesson. I begin the Science Talk for this lesson by gathering the preservice teachers in a semicircle so that everyone faces each other and asking them to imagine themselves as third graders. I have a tennis ball (or any familiar small ball) and start tossing it up in the air. I begin by saying, “I have noticed that many of the games that you play during recess involve objects like this one. Can anyone tell me about some of these games?” This typically elicits many raised hands in an elementary classroom because children don’t usually get asked about games they play. I address any gender stereotypes when discussing this theme, and I am sensitive to any students who may have a physical disability. Consideration of the “funds
of knowledge” (Moll et al. 1992) that students bring with them from their different cultural backgrounds could lead into some interesting discussions about the games that they play.

Demonstrating the games by acting them out can help English language learning (ELL) students understand them better. Using actual pictures to show different types of games is also a good idea. I emphasize how useful it is to use visuals and encourage my preservice teachers to always use them. When a visual is not available, eliciting stories of games students play with balls is sufficient to start the conversation. Another activity to support and include ELL students is to have students draw themselves playing a game that involves a ball and then do a pair-share.

A list of the games can be written on the board or chart paper, but the main point of this preliminary question is to set up the next question, “How do you make the ball move when you are playing this game?” I analyze the responses in the moment and any words or phrases that the students say related to the concept of forces and motion are written down. Typical examples include throw, kick, push, and hit. I follow up with, “What happens when you kick or throw the ball? Does it always go in the same direction? Why or why not?” These are intended to have students start thinking and talking about how and why objects move differently. I analyze the responses as before and write down more words and phrases such as different directions, slow, far, and moves.

At this point we have built a word wall using students’ own observations about how a ball moves in a familiar context. ELL students can refer to the word wall to help them practice scientific language. I then introduce the essential questions for the next part of the lesson, “How can we make objects move? Why do objects move differently?” The use of Science Talks at the beginning of this lesson also serves as a preassessment to address any misconceptions that students might have about terms or concepts related to forces and motion.

EXPLORATION

Students now engage in the hands-on investigation to answer the essential questions. This activity is set up as a game designed to meet the following disciplinary core idea: The patterns of an object’s motion in various situations can be observed and measured; when past motion exhibits a regular pattern, future motion can be predicted from it (NGSS Lead States 2013).

Preparation for this activity should be done before the lesson begins. This maintains the momentum created by the Science Talk. The materials are readily available—tennis balls, cans that roll, other round objects; flat tables (or large pieces of cardboard that can be placed on the floor), and masking tape. I emphasize to the preservice teachers that science resources don’t have to be expensive. The preparation takes 10–15 minutes and requires marking an X and two lines with tape on tables or on a piece of cardboard on the floor if tables are not available (Figure 1).

Students work in groups of three or four. Small groups enable students to discuss what they observed and help each other with the task. This is helpful for ELL students because it creates an opportunity for them to “interact with others and negotiate meaning” (Lucas, Villegas, and Freedson-Gonzalez 2008, p. 369) through a purposeful activity. It also allows me to use formative assessment strategies, such as observing and asking questions, to learn several things:

- Do they understand the task?
- What are they observing and discussing?
- How are they adapting to what they are observing?

I then make any necessary adjustments based on what is occurring in the groups. I direct the students to do the following:

- Draw a representation of the table in your science notebook (a worksheet can be provided as an accommodation).
- Place a tennis ball on the X at end of the table.
- Use one finger to tap the tennis ball once to try to make it move and stop between the two pieces of tape.
- Each time the ball moves, collect data on where it stopped in your science notebook.
- Each student has three attempts to make the tennis ball stop between the lines.

![FIGURE 1](Setup for the activity)
• To ensure that all students are equally engaged, I give some additional management instructions:
• Decide the order each student takes their turn.
• Each student hits the ball once and then another student takes their turn.
• Everyone observes each other doing the task.

I demonstrate how to collect the data before the students begin (Figure 2). If the ball goes off the table, then students mark where it went off the table.

While the students engage in the activity, I observe and listen, making mental or written notes about what the students are doing. I note how the students are applying force with their fingers and what they are saying about each other’s attempts. Some typical phrases are, “tap it a little softer,” “tap it a little harder,” “the ball keeps going sideways,” and “this is hard.” These statements show that students are starting to realize another disciplinary core idea: Each force acts on one particular object and has both strength and a direction (NGSS Lead States 2013).

After the students have three attempts, I direct them to put the tennis ball on the X and sit down. The students are asked to examine their data, write their observations and any questions they have. The purpose of collecting and analyzing data is to look for patterns that show how “force acts on one particular object and has both strength and a direction” (NGSS Lead States 2013). Adding an additional element to measure the distance an object moves is a good extension activity, as is doing the same activity with another type of ball. I have used racquet balls, soft foam balls, and baseballs, which all react differently when the same amount of force is applied.

**EXPLAIN**

Once all the students have written their observations and questions, it is time for another Science Talk. Two simple questions guide this discussion: “What happened during the activity?” and “Why did that happen?” I ask the students to look at their data and think about patterns and cause and effect (crosscutting concept). At the same time, I highlight key concepts they are talking about, such as force, distance, motion, and speed. This is also the perfect time to emphasize key terms and skills such as apply, observed, evidence, and data. For example:

**Student:** “When I hit the ball hard it went really far and fell off the table”

**Teacher:** “So, you are saying that when you applied a lot of force it went a long distance?”

This is another opportunity for a formative assessment. Listening to the student explanations about what they observed and questions they have allows the teacher to address any misconceptions before continuing.

**ELABORATE**

At this point, students have begun to recognize key factors that can help or hinder their attempt to make an object move a certain distance. They realize that where and how they apply the force makes a difference, “When I hit the ball on the top it didn’t go as far as when I hit it in the middle.” This is the moment when I guide them toward thinking further about the concept of force and motion. I ask them to predict if it will be easier or harder to do the same activity with a different shaped object such as a can. I show them a can (I have used an empty oatmeal container) and ask them to remember what they have learned in math (CCSS.Math.Content.3.G.A.1) about different shapes: “What is this shape called?” “What was the shape of the tennis ball called?” “How are they different?” Then, going back to the task at hand, I ask, “Why do you think it will be easier or harder to do the activity with the can?” The preservice teachers are asked to share their thinking with a partner, and I walk around listening to their responses. A common argument is that the can will be easier because it can’t “roll around” as much. By this point they are asking if they can do the activity with the can. Anticipation has been built and the students want to know if they are correct in their predictions! Before letting the students conduct the activity, I review the procedures as described in the Explore section. I also remind the students the importance of collecting accurate data because this will be the evidence that they use to make a claim about whether it is easier or harder to do the activity with the can. The les-

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**FIGURE 2**

**Collecting data.**

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<th>X</th>
<th>O (1)</th>
<th>O (2)</th>
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season ends with another round of a Science Talk that focuses on students explaining why they believe it is easier or harder to move the can a certain distance and some closing questions that can be investigated further in a future lesson: “What if the surface was a different material?” “What if we used another object to apply the force?”

**EVALUATE**

Formative assessment practices are used throughout the lesson to guide the teacher in helping the students understand the concepts being taught. By emphasizing this “assessment for learning” strategy, which focuses on improving student learning (Hargreaves 2005), I am shifting the focus away from the typical summative assessment and all the trappings that can come with it (Rosemartin 2013). Asking the students to share their work while they are engaged in the learning process gives me an opportunity to address misconceptions and questions at the moment they arise. The time invested in real-time, corrective feedback yields substantial gains in summative assessments given later.

**DISCUSSION**

This lesson was first done in a college classroom with preservice teachers. I then discussed the idea of my students teaching it in a third-grade elementary classroom with a teacher I have worked with previously. She recruited other third-grade teachers. In preparation, we discussed the importance of making sure the lesson was designed to include all the students. Some ways that this lesson applies differentiated learning are:

- Students work in small groups, enabling the teacher to reteach or add extension activities.
- Students can express their thinking in writing, verbally, and visually.

The level of engagement and outcomes were similar for the preservice teachers and the third graders. They talked enthusiastically about how much force and where they applied the force affected the object’s movement. They both also began to speculate on how the surface material or stability of it affected the object’s movement. Adaptations were made when the preservice teachers taught the lesson in the third-grade classrooms. Each preservice teacher worked individually with a group of four students in several third-grade classrooms for 45 minutes. This allowed them to hear the full conversations that the students had during the activity. We also decided that it would be best to conduct the activity on a cardboard surface because not all the third-grade classrooms had tables. This allowed for the lesson to be conducted on tables, desks, or the floor.

**CONCLUSION**

It was interesting and satisfying to watch college students having fun while relearning some basic concepts related to force and motion. Some of them had not taken a physical science class since high school and thought that it would be difficult to teach this type of lesson. Many of them have been taught by the teacher telling them what the concepts are rather than letting them discover on their own. The idea of not overloading students with terms and concepts in the beginning of a lesson was difficult for the preservice teachers. However, once they started seeing and hearing their students talk about terms and concepts on their own, it changed their thinking from only focusing on teaching science content to focusing on teaching how to DO science.

**REFERENCES**


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Connecting to the **Next Generation Science Standards** (NGSS Lead States 2013)

**Standard**

3-PS2 Motion and Stability: Forces and Interactions


- The chart below makes one set of connections between the instruction outlined in this article and the NGSS. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.
- The materials, lessons, and activities outlined in this article are just one step toward reaching the performance expectation listed below.

**Performance Expectation**

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.

<table>
<thead>
<tr>
<th>DIMENSIONS</th>
<th>CLASSROOM CONNECTIONS</th>
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<tbody>
<tr>
<td><strong>Science and Engineering Practice</strong></td>
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<tr>
<td><strong>Analyzing and Interpreting Data</strong></td>
<td>Students engage in science talks to describe patterns of objects’ motion based on collected data.</td>
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<tr>
<td><strong>Disciplinary Core Idea</strong></td>
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<tr>
<td><strong>PS2.A: Forces and Motion</strong></td>
<td>Students compare the placement and amount of force on the direction and movement of different objects (sphere, cylinder). Students observe and record patterns of movement to make predictions of the future motion of different objects.</td>
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<tr>
<td>Each force acts on one particular object and has both strength and a direction. 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.</td>
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<td><strong>Crosscutting Concept</strong></td>
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<td><strong>Patterns</strong></td>
<td>Students use observations and collect data to identify patterns of motion of objects.</td>
</tr>
<tr>
<td><strong>Cause and Effect</strong></td>
<td>Students explain how the direction and strength of force affect the movement of objects.</td>
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Connecting to the **Common Core State Standards** (NGAC and CCSSO 2010)

| Mathematics | |
| **CCSS.Math.Content.3.G.A.1** | Understand that shapes in different categories may share attributes, and that the shared attributes can define a larger category. |