# Collaboration *Physics*

*Elementary teachers and university researchers join forces to help students construct understandings of friction—and discover something of the nature of science in the process.*

By Danielle Harlow and Valerie K. Otero

What do you get when you mix university curriculum developers with motivated elementary teachers? … An awesome learning collaboration that benefits researchers, teachers, and students! That's what we discovered when we—university researchers involved in the Physics for Elementary Teachers (PET) project—teamed up with local elementary teachers to develop effective inquiry-based physics lessons for second- and third-grade students enrolled in an after school science program.

We all gained from the teamwork—this article describes our experiences implementing a collaboratively developed lesson on friction.

## A Format to Follow

We began our collaboration by holding a workshop for three elementary teachers and their district science coordinator using a preliminary version of the PET curriculum (see "PET Project," page 39). At the workshop, the elementary teachers participated in inquiry-based lessons to learn about various physics topics.

At the end of the workshop, we began to meet with the elementary teachers each week to develop inquiry-based activities on these same topics for use in an after school program. We decided the units for students would follow the format the teachers used at the workshop, a learning cycle of Elicitation, Exploration, Explanation, and Consensus Building:

- *Elicitation:* The teacher begins the unit with an activity designed to discover what students already know about the topic.
- *Exploration:* The children work together in small groups to make sense of the observed phenomena.
- *Explanation:* The children are expected to show the class their ideas and the drawings they create on presentation boards and to share their ideas verbally with the entire class.
- *Consensus Building:* The teacher leads students in a discussion during which the children make sense of their observations and collectively create ideas that describe the observed phenomena.

This approach allows children to develop science ideas in a manner consistent with the way science is done, thereby developing an understanding of the processes and norms of scientific inquiry.

We developed concrete lesson plans for each student activity we created. The friction lesson plan appears on page 37; a description of the lesson's implementation follows.

## The Implementation

This lesson was presented in an after school program targeted toward populations who are underrepresented in science. The 16 students were taught by two elementary teachers and observed by three university researchers.

The lesson exploring friction was designed to address the following objective: Toy cars slow down because the surface exerts a push against the motion of the toy cars.

When we constructed the lesson, we anticipated that students' ideas about why the car slows down would align with one of many commonly held conceptions, such as that of an "impetus theory," a common belief about motion among children of all ages (Gunstone and Watts 1985; McClosky 1983). The impetus theory generally states that an object stops moving because it runs out of *force*. Children who hold this conception believe that *force* is a property of the object that is moving. This is different from the scientific understanding that a *force* is applied to an object only through some sort of interaction. An object slows down because it is acted on by *friction*, a force against motion between the object and the surface that the object is moving across.

We designed our car activity assuming that students would have the belief that force is a property of the object.

## Elicitation

### Students' Ideas About Friction

In our lesson, the teacher began the activity by asking, "Imagine that you had a toy car and there was no ramp. If the car was just on something flat, and you gave it a little push, what would happen to that car?" If a student thought it might start slowing down after a while, the teacher asked, "Why do you think it would slow down?"

Although we anticipated students would describe some sort of impetus theory, none of the students stated that the car stopped because *force* ran out of the car. Rather, the children mentioned batteries and gravity. One even stated that it would "just keep going." Although a few students mentioned rocks or cracks in the sidewalk, most did not seem to have the idea of friction as a force.

Although the students' prior knowledge was not exactly what we anticipated, we continued with the activity as planned, thinking that the activity was useful in moving students toward an understanding of friction as a force (or a push) against motion between the surface and the object.

In designing the activity, we had reasoned that if we used a very rough grade of sandpaper as a surface, students could visualize the little bumps as pushing against the car and extend this understanding to smoother surfaces by using successively smoother grades of sandpaper.

For students who might not make the connection between the sandpaper bumps and the idea of "push," we designed *hand boards* made up of a succession of very small sticky notes bent upward with the palm of a hand drawn on each one (Figure 1, page 37). We figured that if students rolled the car through the succession of sticky notes, they might visualize the hands as signifying the concept of "push."

## Exploration

### Testing with Toy Cars

In the exploration, students worked in groups of four to observe the effects of various surfaces on a toy car's movement after it goes down a ramp (For complete instructions, see the friction lesson plan on page 37).

Students placed the different surfaces—the hand board and three grades of sandpaper—at the end of the ramp and measured the distance the car traveled on each surface. They also did a trial measuring the distance the car traveled on the smooth floor.

As students conducted their tests, the teachers circulated among the children and asked them to explain what they were thinking might be happening. Most of the students readily told the teachers that the car slowed down and eventually stopped when it had traveled a short distance on the sandpaper.

The teachers then asked the groups directed questions, such as, "What are the little hands on the sticky notes doing to the car?" "What do you think the bumps on the sandpaper are doing to the car?" and "How are the bumps like the little hands?" to guide students toward thinking of the sandpaper as similar to the little hands on the hand board's papers pushing the car against its motion and making it slow down.

The teachers' goal was for students to understand that even a surface that appears smooth, like the floor, has small bumps in it that slow the car.

## Friction Lesson Plan

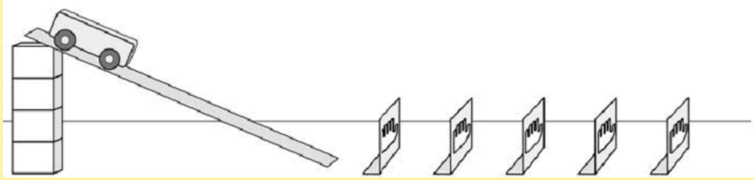
**Objective:** Toy cars slow down because the surface exerts a push against the motion of the toy cars.

**Time needed**: Fifty minutes.

**Materials:** Ramp, blocks, toy cars, rulers, three types of sandpaper (smooth, medium, and rough), and a *hand board.* A hand board is a board with small pieces of paper (sticky notes) attached to the board and bent so that the papers are standing up, as shown in the illustration above. Each piece of paper has a small hand drawn on it.

**Figure 1.**

Hand board illustration.



**Procedure:**

**Elicitation:** The teacher leads students in a discussion about what they believe causes the toy car slow down.

**Exploration:** Students measure and compare the distances the toy car travels on several surfaces (in this order):

1) The hand board;
2) Three grades of sandpaper (rough, medium, smooth); and
3) The floor.

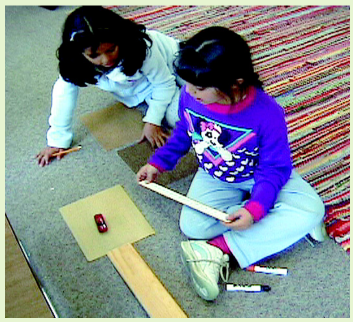
The students should run their first trial with the hand board placed at the base of the ramp. The hand board is designed so that the students can actually see the paper pushing against the car and slowing the car down.

Because the students can see the bumps on the rough sandpaper, they should be able to relate the rough sandpaper to the hands pushing against the car and determine that with the sandpaper, the little bumps are pushing the car and causing it to slow down.

The last three trials with the medium sandpaper, the smooth sandpaper, and finally the floor, should lead students to extrapolate that even on the smoothest floor, there are tiny bumps that push against the car and cause it to stop.

**Explanation:** Students draw pictures on presentation boards that illustrate what they think causes the toy car to slow down.

**Consensus Building:** The teacher leads students in a discussion about what they believe causes the toy car to slow down.



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After exploring how cars moved and stopped on various surfaces, students began to appreciate that the cars stopped because something was pushing against them.

The students then constructed graphs on small dry-erase boards that showed the distance the car traveled (on the $x$-axis) compared to the "roughness" of sandpaper (on the $y$-axis). The students' representations all showed that the smoother surfaces allowed the car to travel farther and that the rougher the surface, the less distance the car traveled.

## Explanation

### All About the Bumps

At the end of the activity, each group presented their ideas to the class. The students worked within their groups to construct a reasonable explanation of the observed phenomena on their dry-erase boards, which the children used to present their results and to refer to as they shared their ideas.

In their presentations, every student claimed that the bumps were somehow important to the car's decrease in speed and eventual stop. They talked about bumps "stopping," "crashing," and even "pushing" the car.

As we had hoped, some students noticed that the little bumps in the sandpaper were—like the paper hands—stopping the car. One child stated, "We think that the cars are stopping because the bumps block the cars from going really fast. It loses its speed when it crashes into the bump."

Similarly, another child noticed that the bumps in the sandpaper were important. He compared the bumps in the sandpaper to objects that the toy car crashed into, causing it to lose speed, "I drew a picture about a car crashing into a bump and then it losing its speed—it's kind of like crashing into it and starting all over but with less speed."

Children enjoyed writing and drawing their ideas on the board, and the dry-erase boards soon became the norm for presenting results in the science club. The advantage to using dry-erase boards is that students must work together to create a shared representation of their ideas and that dry-erase boards are easy to edit as children change their ideas by talking with one another. One drawback of using the dry-erase board is that the students' work is not permanent. We believe that the editable nature of the board outweighs this drawback, so we have begun to take digital photos of the boards to save as permanent assessment data.

## Consensus Building

### Making Sense of Observations

In the elicitation phase discussion, students had described the toy car stopping because of "batteries," "gravity," and, as one student said, "it just stops." After exploring how cars moved and stopped on various surfaces, students had made considerable progress toward changing these initial ideas. They came to an understanding of friction as a force (or a push) against motion between the surface and the object. In this case, they began to appreciate that the car stopped because something was pushing against it.

During this consensus building part of the lesson, students agreed on the conclusion that cars stop because they hit tiny bumps. In other words, the mechanism for slowing the car comes from the surface on which the object is moving. The words *force* and *friction* were not introduced during this lesson. Later lessons would introduce the scientific terms, but only after students had developed their own shared language to describe their observations.

## Connecting to the Standards

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

### Content Standards

**Grades K–4**

**Standard A: Science as inquiry**

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

**Standard B: Physical science**

- Properties of objects and materials
- Position and motion of objects

**Standard G: History and nature of science**

- Science as a human endeavor

## PET Project

Physics for Elementary Teachers (PET) is a National Science Foundation–sponsored curriculum development project conducted collaboratively by researchers at San Diego State University, Tennessee Technical University, and the University of Colorado at Boulder. PET is designed to help elementary teachers learn physics through guided inquiry and collaboration.

The premise of the project is for teachers to explore physics concepts through hands-on activities from the PET curriculum and then do "homework" in which teachers apply their developing understandings of physics by analyzing videotapes of elementary students working through activities similar to those in the PET curriculum.

The PET curriculum is a special physics course that enhances elementary teachers' abilities to use their content knowledge to help children develop emotionally and intellectually.

As PET curriculum developers, our first step was to develop inquiry-based lessons on many physics topics, including force and motion. We also needed to obtain video of children working with physics concepts and learning and talking about physics. We realized that we would benefit from working with practicing elementary teachers in developing the lessons and that the elementary teachers would benefit from participating in inquiry-based physics, hence the success of our collaboration.

We assessed students' understanding of the concept of slowing and stopping because of a push against the motion of the object by having students construct explanations for why a block slows down and stops on a smooth surface, like a tabletop, after it has been given an initial push. This helped us understand whether students had made the connection between the sandpaper and smoother surfaces, and whether they had developed ideas about slowing and stopping as a result of a push rather than as a property of the object.

## Scientists Like Us

Many of the students participating in the after school program were English Language Learners in their first year in an all-English classroom at their bilingual elementary school. We found the "Elicitation, Exploration, Explanation, and Consensus Building" process extremely useful for the students.

In the Explanation discussions, particularly, students were able to practice English, public-speaking, and reasoning skills as they shared their ideas with the group. The process of establishing ideas through Consensus Building was also valuable to students. As students described their observations and formulated ideas about what they had learned, they were beginning to think of themselves as creators of knowledge, like scientists. Just as scientists develop relationships in order to explain phenomena—students too had developed a relationship (through the activity) to learn about friction.



Best of all, these experiences helped children begin to understand an important aspect of the nature of science—that science knowledge is developed through the use of creativity, prior knowledge, investigating, and consensus of people—scientists just like them.

For the teachers, this experience helped generate understandings of the value of standards-based instruction designed to allow children to generate their own complex ideas through carefully designed experiments that build on the students' own ideas.

For us, the researchers, this was an eye-opening experience that demonstrated the art and science of elementary teaching as the weaving together of intelligence, creativity, emotion, differentiation, management, and a deep understanding of young students as intelligent human beings who are capable of anything a clever teacher has the courage to try.

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### Acknowledgment

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### Resources

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### Internet

Physics for Elementary Teachers (PET)
*http://cpucips.sdsu.edu/web/pet*