GRAVITY RACERS

The classroom becomes a scene out of the winter Olympics as students design and build a gravity-powered car.

By Dawn Renee Wilcox, Shannon Roberts, and David Wilcox

Children experience the principles of motion on a daily basis as they play with toy cars, zoom down a slide, or coast downhill on a sled. With the 2010 Winter Olympic Games prominent in the media, our children were exposed to images of athletes skiing down snow-covered slopes, coasting furiously on bobsleds, and skating gracefully across the ice.

We capitalized on our children's natural curiosity about the world around them by exploring the concept of motion. Our weeklong series of science, technology, engineering, and math (STEM) activities provided the opportunity for us to lead a 21st-century instructional approach to science education that involved hands-on and direct experiences for our students. To do this we used a 5E

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Students explored motion before designing their vehicles.

learning cycle model (Engage, Explore, Explain, Elaborate, Evaluate) as students investigated force and motion (Bybee 1997). Students designed, built, and tested their own simple gravity-powered car using experimentation and active investigation; essentially, they modeled thinking processes that are similar to those applied by scientists as they gathered information. We carried out this activity in a fourth-grade classroom, but it could be used with grades 3–5 with slight modifications.

Engage

The experience began with a challenge encouraging students to design a racing vehicle for a new Olympic racing event, "Gravity Racers." In this event, athletes would travel down a slope (inclined plane) in a straight line for a determined distance powered only by gravity. We told the students that they would work in design teams and would be in charge of conducting experiments to develop an understanding of the position of an object and of the forces that cause that object's motion.

Explore

The lesson continued with an exploration session. Students assembled into groups of three to five students. They were encouraged to explore using a ramp and a variety of objects. Our ramp was a simple sheet of thin wood propped against a 10-cm high stack of textbooks. The objects included vehicles with wheels, balls, blocks of wood, marbles, or pennies. We encouraged students to discover movement by allowing them to explore freely, test their predictions, and discuss their ideas about motion with others.

As the students became comfortable in their explorations, we encouraged them to move toward more formal data recording. Students were asked to create their own series of miniexperiments. The instructions to the students followed a simple format with each object. First, they asked themselves, "How will my object move?" Next, they predicted how their object would move. Last, they investigated how their object moved. Students used a handout titled *How does it move?* to guide their investigations (see NSTA Connection). They recorded which objects moved in straight or curved paths and which vehicles traveled the farthest using simple data tables. They determined the average distance traveled by each vehicle. This data helped facilitate a discussion in an effort to increase student understanding during the explanation portion of the lesson.

During recess we took the students on a "motion walk" around the school yard, stopping at intervals to notice examples of motion. When we returned to the classroom, we created a list of examples. Those examples included balls dropping and bouncing, a teacher pushing a cart, wheels on the cart rolling, and students gliding down a sliding board. The engagement, exploration, and motion walk provided a foundation for later activities in which we took these common real-world (playground) experiences with motion and gradually introduced the concepts of forces, reactions, gravity, friction, and inertia.

Explain

Next, we allowed students to reveal what they already knew about force and motion and gave them the opportunity to organize and build on background knowledge. The goal was for students to realize that every movement is caused by a push or pull and to develop an understanding of the concepts of inertia and friction. To guide students, we asked them to analyze and classify their movements as pushes or pulls. We allowed students to discover on their own that a pull is sometimes gravity by creating their own explanations and listening to the explanations of others. Toward the start of the lesson, student answers indicated they believed that objects stop on their own. One student commented, "The ball rolled down the ramp then stopped by itself." Another student remarked, "The car rolled fast, then it stopped. Yes, all by itself!" Later in the lesson student thinking shifted. Students realized that something must be acting on the object to stop it or slow it down. A student noted, "If you roll a ball down the ramp it speeds up because of gravity." We developed an understanding of *inertia*, the property of matter by which an object retains its state of rest or its velocity along a straight line so long as it is not acted upon by an external force. To encourage students to develop an understanding of inertia, we helped them build on prior knowledge and construct relations between force and motion. We demonstrated the old *pull the tablecloth out from under the objects trick*. The students saw firsthand that the objects on the table will not move unless acted on by an outside force. We also asked the students to experiment with stopping the objects and changing their direction. We asked questions like: Which objects roll? Why do some objects move without rolling? What causes the objects to slow down or stop? Initial comments included statements like, "The block won't move." We noted a conceptual change as student comments moved toward statements like, "If I push the block, it will slide down the ramp" and "The car hit Eleanor's leg, causing it to stop and change direction." These responses showed that students recognized that when things speed up or slow down there is a cause.

Figure 1.

Vocabulary matching game.

Directions: Print on cardstock. Cut apart.
Match the vocabulary word to the correct definition.

Energy	The ability to do work
Speed	A measurement of motion
Inertia	The property of matter that causes it to resist any change of its motion in either direction or speed
Friction	The resistance to motion created by two objects moving against each other
Kinetic energy	Energy in motion
Potential energy	Energy that is not in motion, but could be

We encouraged the integration of mathematics concepts by asking questions like: How far did each object move? Does the height of the ramp affect how the object moves? We carried the force and motion theme outside of our science time frame into our reading and language arts lessons. We encouraged students to explain their understanding of the concepts of motion through a vocabulary game and encouraged students to use the words as they carried out the challenge. A copy of the vocabulary matching game is presented in Figure 1. Students also read literature that related to the concepts (see NSTA Connection).

Elaborate

In the two or three days that followed, we gave students the opportunity to apply their new knowledge about motion as they participated in our motion design challenge. Students were required to collect and display data as they developed abilities to identify and state a problem, design/implement a solution, evaluate, and communicate with teachers and classmates.

Identify a Problem

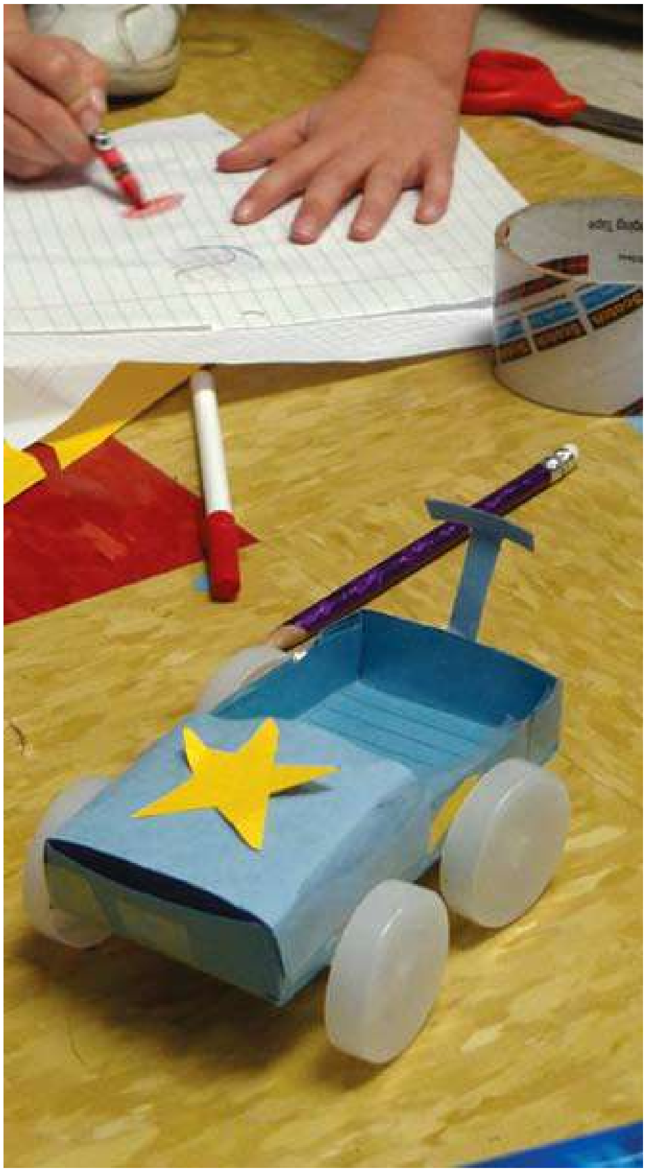
We set the students up in design teams so that they could conduct experiments with motion and force to meet the design challenge. Our guidelines were that the car should have a chassis no smaller than 8 cm wide and no longer than 30 cm from bumper to bumper. We also explained that the vehicle should be able to roll down the ramp and travel for at least 100 cm.

Propose a Solution

Students were next asked to sketch a scale drawing—including measurements—of a vehicle to meet the design challenge. They communicated their design ideas to their teachers and their classmates in a show-and-tell fashion, allowing the opportunity for the teacher to capture student thinking.

Implementing a Proposed Solution

We gave students different materials to choose from (cardstock, construction paper, tissue paper, cardboard milk cartons, dowels, paper clips, pipe cleaners, straws, wheels, Styrofoam trays, spools, craft sticks, plastic bottles, glue, tape, scissors) as they followed the stages of technological design. The students worked collaboratively, using a variety of simple materials to create their vehicle. The materials listed are just a few examples of items that may be used. Feel free to use your imagination when choosing items for your students to use in their construction plan. In addition, rulers, stickers, paint, and other art materials might be useful to students. Throughout the design process, we encouraged students to raise questions, develop hypotheses to test, and use their imaginations. We required students to record data in the forms of charts and diagrams and explained that we would use their individual or group data to create a class graph. We tied their data analysis scenario to the real world of Olympic athletes as they measured and recorded their best times to determine who qualified to compete and win the medals. Students tested their cars by placing each at the top of the ramp and releasing them. Then we asked students to record the distance each team's vehicle traveled down the ramp and encouraged them to use that data to create graphs to show the distance in which their vehicles traveled. Students followed a scientific procedure to test their vehicle as they followed a prepared data-recording sheet (see NSTA Connection).



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Each racer was tested to determine the best time.

Evaluate and Communicate

Students analyzed their data and the data collected by other students to determine how well their design met the challenge. Students completed a checklist on their worksheet (see NSTA Connection). Again, students used measurements and communicated their findings orally and through writing. At this point in the lesson, we gathered the students together in one large group. Students reported their best times to the class and we recorded the data on our class chart. They modeled or talked about their successes and failures as they worked to meet the challenge. For example, one student commented, "I thought my car would go faster if I painted it orange. I learned that paint doesn't make it go faster." Students were able to do this because throughout the process we encouraged them to make careful observations and discuss what was happening to their vehicle. We monitored the students as they discussed, examined, critiqued, explored, argued, and struggled with the challenge. We encouraged the students to explain the concepts and definitions in their words and to justify and clarify their ideas. Student comments included statements like, "A push or a pull is a force" "A push can change the direction of my car" and "A push can make my car go farther." We helped them to understand the science behind the concepts by asking questions: What happened to the car? Did it travel in a straight line or turn? How might you get it to turn left or right? How far did it travel? How might you get it to travel farther? How might you get it to stop sooner or travel faster?

Not all of the students' cars traveled in a straight line the first time they rolled them down the ramp. Some cars curved to the right or left. One car had wheels that would not turn; that car just sat on the ramp. Students made design modifications and adjustments to their vehicles based on their findings, allowing for a discussion about cause-and-effect relationships and for us to focus on these changing quantities called *variables*. One student commented, "Wheels made it easier to push my car. The car without wheels takes more force to move." Another student reported, "When we tested our car the first time, our car rolled down the ramp and turned to the left. We adjusted our car by modifying how the straw [axle] was taped onto the car body and then it rolled straight." We introduced the students to the BBC Science Clips: Forces and Motion during this point of the lesson (see Internet Resources). The activity allows students to conduct a simulated experiment. The students can manipulate a number of variables and then push their car down the ramp. They are able to change the amount of force, the height of the ramp, and the size of the vehicle.

Assessment

We used an investigation rubric to assess understanding and progress (see NSTA Connection). Students were also asked to present an oral and pictorial version of their design and solution to communicate with classmates and teachers. Our students prepared a simple show-and-tell presentation. We used an oral communication rubric to assess understanding as well (see NSTA Connection). Other possible presentation methods might include: discussions, written reports, and computer presentations.

Extend Ideas

We finished by reinforcing the concepts. We extended the lesson by providing opportunities for students to apply their new knowledge in real-world situations outside of the classroom (e.g., relay races in physical education class, playground games, video clips, internet activities, bus ride home). At this point in the lesson, we visited Edheads Crash Scene Investigation website (see Internet Resources). This website contains information that helps kids learn about different professions and career choices in science.

Encourage students as they apply their new definitions, explanations, and skills to new but similar situations. The Rader's Physics for Kids! Motion website contains definitions and pictures that the teacher or students can access to reinforce the motion concepts (see Internet Resources).

Extend lessons by helping students summarize the relationships between the variables in the lesson. Teaching motion through STEM gave students the opportunity to connect real-world situations like playground games and sports to instruction in the classroom. The design challenge unified science, technology, engineering, and mathematics by placing the learning into a context that provides meaning and hands-on learning experiences intended to encourage students to develop an understanding of position and of the forces that cause an object's motion. ■

Connecting to the Standards

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

Grades 5–8

Content Standards

Standard B: Physical Science

- Motion and forces

Standard E: Science and Technology

- Abilities of technological design
- Understanding about science and technology

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

***Dawn Renee Wilcox** (dwilcox@spotsylvania.k12.va.us) is the science coordinator at Spotsylvania County Schools in Fredericksburg, Virginia. **Shannon Roberts** is a fourth-grade teacher at Cedar Forest Elementary School in Fredericksburg, Virginia. **David Wilcox** is a student interested in expanding understanding in experiential learning at Central Wyoming College in Riverton, Wyoming.*

Reference

Bybee, R.W. 1997. *Achieving scientific literacy: From purposes to practices.* Portsmouth, NH: Heinemann.

Internet Resources

BBC Science Clips: Forces and Motion
www.bbc.co.uk/schools/scienceclips/ages/6_7/forces_movement.shtml

Edheads Crash Scene Investigation
www.edheads.org/activities/crash_scene

Rader's Physics for Kids! Motion
www.physics4kids.com/files/motion_intro.html

NSTA Connection

Download a reading list, rubrics, and worksheets at *www.nsta.org/SC1003.*