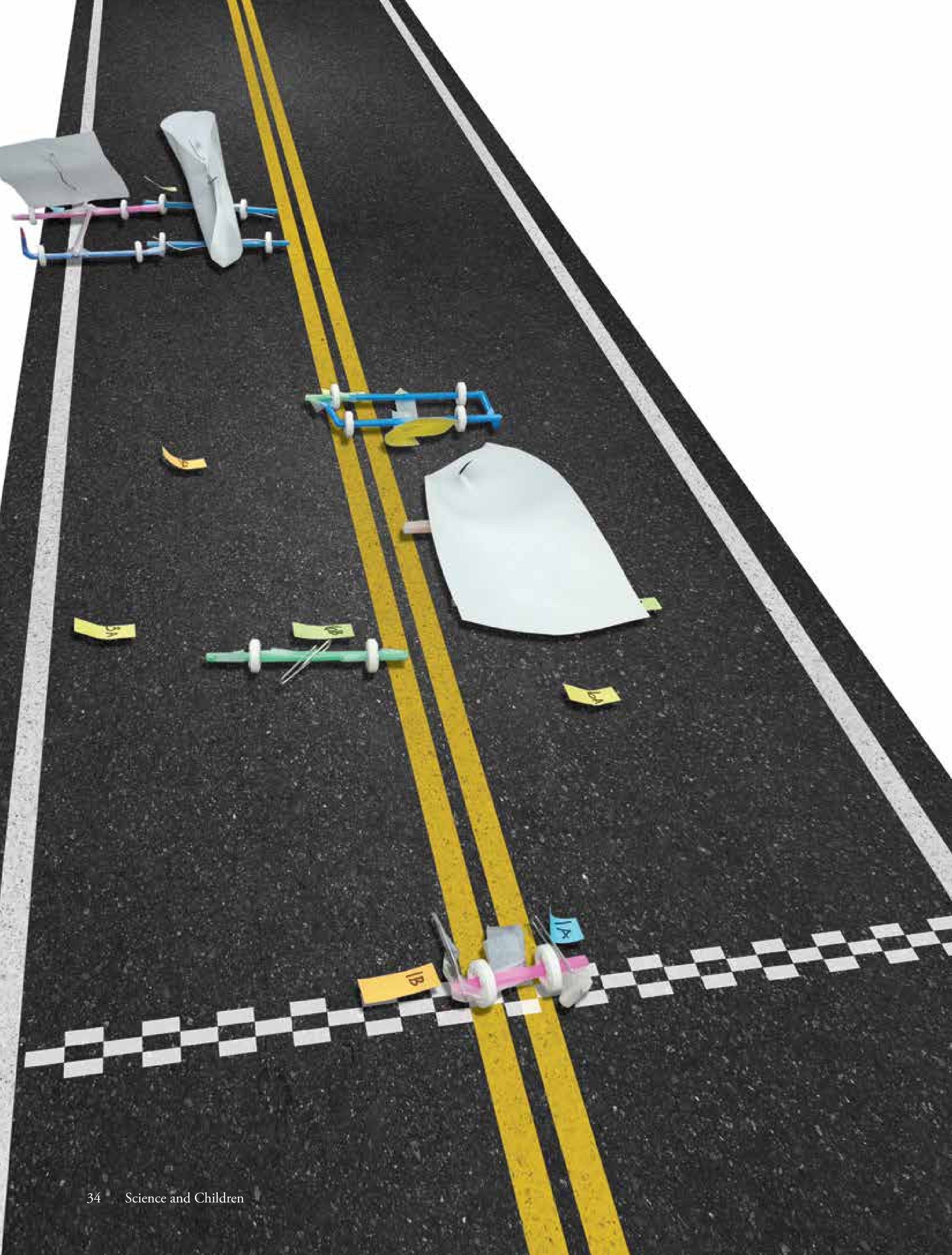


SCAMPERing Into Engineering!

A "snapshot of science" program brings science and engineering into the library.

By Jenny Sue Flannagan and Margaret Sawyer

"Whoa! Did you see that thing zoom off the shelf?" exclaimed one of the fourth-grade boys as his group watched him test his "airmobile" on the library counter. The excitement in their eyes was apparent as they stood by, waiting patiently to test their own cars next.

When our school division was asked to make more explicit connections to engineering, we wondered how we would fit it in. With the heavy emphasis on reading and math in elementary classrooms, adding science to an already crowded day seemed a daunting challenge. But in thinking outside the box a little and looking for natural ways to bridge engineering design projects with science units, we have found a way not only to make it work for us but also creatively engage students in what they love—science!

The lesson described here is part of what we like to call our "Snapshots of Science" program. These mini-lessons of science are taught once a week to all students in the school library. Yes—you read that right—in the school library! Over the last two years, we have been working to extend the experiences students have in their science classroom into the library. Each week, students experience a lesson that goes a little further than their classroom experience. These "snapshots" are only 20 minutes in length and are tied to the state standards. Although they are done in a short amount of time, we have found it is enough time to get students excited to learn more. By using the 5E approach to break our lesson unit into smaller parts, our students are able to focus on one concept or skill and build upon what they learned each week while having time between our library lessons to discover and explore the material we are covering. These lessons provide students with an opportunity to do even more hands-on activities that are different than the ones done in their classroom. These snapshots also provide children with the freedom to explore their activities without having to take home their work each night for additional study.

The snapshot lesson SCAMPERing Into Engineering was designed around the fourth-grade curriculum unit Forces and Motion. Forces and Motion is a four-week science unit that engages students in the study of motion (see Figure 1, p. 37, for Unit Knows, Understand, and Dos). Activities engaged students in designing simple investigations to test how mass is related to motion and how different surfaces affect friction, and students learned to identify and explain when objects exhibited potential and kinetic energy.

There are points in the science curriculum where engineering naturally lives—topics where there is a natural connection between science and the opportunity to integrate math and engineering. For instance, teaching simple machines and motion would easily provide opportunities to plan units where students are actually able to design something that demonstrates the basic concepts and apply that material to an engineering activity. For us, the unit on motion was the perfect time to introduce students to the idea of engineering. We wanted our students to understand that engineers often take the research done by scientists and use it to solve a real-world problem. One real-world problem associated with cars and motion has to do with overcoming air resistance. Knowing that we could not have our students design a real car, we chose instead to engage them in designing a car when given some simple materials. In order to solve the problem, they would have to apply what they had learned and what they would learn about air resistance and friction. This engineering problem also allowed us to introduce students to a simple strategy they could use in the design process.

PHOTOS COURTESY OF THE AUTHORS

Students' first challenge involved using simple materials to design a car that could move with only a breath of air.

Engage and Explore: Transferring Learning to New Situations

This lesson in the library occurred over four weeks. During the first week, students were given a simple yet challenging task—design a car that moves with a single breath of air using only the following items: four Lifesavers (any similar-shaped candy will do), two straws, two paper clips, scissors, tape, and a sheet of paper. They were given no instructions on *how* to build their vehicles, only to design one they thought would work using air power. Students were told there was no "right" or "wrong" answer; their goal was simply to design a wind-powered vehicle. Children who struggled to get started were given the same hint: think about things that move with air. The children at their table would then begin to offer ideas like kites, blimps, sailboats, hang gliders, and hot air balloons. Students were allowed to work as individuals or within small groups at their table. Most children chose to work alone, but the children at their tables often provided guidance when the student was faced with a dilemma.

CAUTION

Students were reminded of safety rules regarding scissor safety and responsible use of paper clips. Given that this activity did not have any rubber

FIGURE 1.

What to Know, Understand, and Do for the unit.

Know:

- The position of an object can be described by locating it relative to another object or to the background.
- Tracing and measuring an object's position over time can describe its motion.
- Speed describes how fast an object is moving.
- Energy may exist in two states: kinetic or potential.
- Kinetic energy is the energy of motion.
- A force is any push or pull that causes an object to move, stop, or change speed or direction.
- The greater the force, the greater the change in motion will be. The more massive an object, the less effect a given force will have on the object.
- Friction is the resistance to motion created by two objects moving against each other. Friction creates heat.
- Unless acted on by a force, objects in motion tend to stay in motion and objects at rest remain at rest.

Understand:

- The pattern of an object's motion in various situations can be observed and measured.
- Regular patterns of an object's motion can be used to predict future motion.
- Patterns of failure of a designed system can be used to improve design.

Do:

- Describe the position of an object.
- Collect and display in a table and line graph time and position data for a moving object.
- Explain that speed is a measure of motion.
- Interpret data to determine if the speed of an object is increasing, decreasing, or remaining the same.
- Identify the forces that cause an object's motion.
- Describe the direction of an object's motion: up, down, forward, backward.
- Infer that objects have kinetic energy.
- Design an investigation to test the following hypothesis: "If the mass of an object increases, then the force needed to move it will increase."
- Design an investigation to determine the effect of friction on moving objects. Write a testable hypothesis and identify the dependent variable, the independent variable, and the constants. Conduct a fair test, collect and record the data, analyze the data, and report the results of the data.

**Knows and dos are from the 2010 Science Standards of Learning Curriculum Framework found at *www.pen.k12.va.us/testing/sol/standards_docs/* science/index.shtml

bands or other projectile pieces, we did not require all students to wear goggles, but they were available for students wishing to use them. When students tested their cars to see how far the vehicles would move using their breath, only one student was allowed at the counter at a time, while the other students remained at the group tables and observed from there. Constant teacher supervision was provided.

As they built and tested their cars, students were instructed to take notes of what they observed the car doing. Students made note of whether their cars moved, how their cars moved, and the distance their cars moved along the counter. At the conclusion of this lesson, students were assessed using a 3-2-1 exit ticket. They shared three things they had observed about their car, two questions they still had about the cars or designs, and one thing they wanted to change during the next week's lesson. We felt this provided us with a glimpse into what students were observing and wondering.

Explain: Thinking Like an Engineer

During week 2, we introduced students to the concept of an engineer and explained to students what engineers do. This allowed for the perfect opportunity to introduce the

FIGURE 2.

S.C.A.M.P.E.R.

When to Use the Strategy:
Use it when you want students to think creatively to change the design of something.

How to Use the Strategy:
Have students take an existing object, product, or service. Use the question stems to help you brainstorm things you could change or modify. When done, look at the various answers. Which ones could you try to see if they make a difference?

Substitute

- What materials or resources can you substitute or swap to improve the product?
- What other product or process could you use?
- What rules could you substitute?
- Can you use this product somewhere else, or as a substitute for something else?
- What will happen if you change your feelings or attitude toward this product?

Combine

- What would happen if you combined this product with another to create something new?
- What if you combined purposes or objectives?
- What could you combine to maximize the uses of this product?
- How could you combine talent and resources to create a new approach to this product?

Adapt

- How could you adapt or readjust this product to serve another purpose or use?
- What else is the product like?
- Who or what could you emulate to adapt this product?
- What else is like your product?
- What other context could you put your product into?
- What other products or ideas could you use for inspiration?

Modify

- How could you change the shape, look, or feel of your product?
- What could you add to modify this product?
- What could you emphasize or highlight to create more value?
- What element of this product could you strengthen to create something new?

SCAMPER is a mnemonic that stands for:

Substitute.
Combine.
Adapt.
Modify.
Put to another use.
Eliminate.
Reverse.

Put to Another Use

- Can you use this product somewhere else, perhaps in another industry?
- Who else could use this product?
- How would this product behave differently in another setting?
- Could you recycle the waste from this product to make something new?

Eliminate

- How could you streamline or simplify this product?
- What features, parts, or rules could you eliminate?
- What could you understate or tone down?
- How could you make it smaller, faster, lighter, or more fun?
- What would happen if you took away part of this product?
- What would you have in its place?

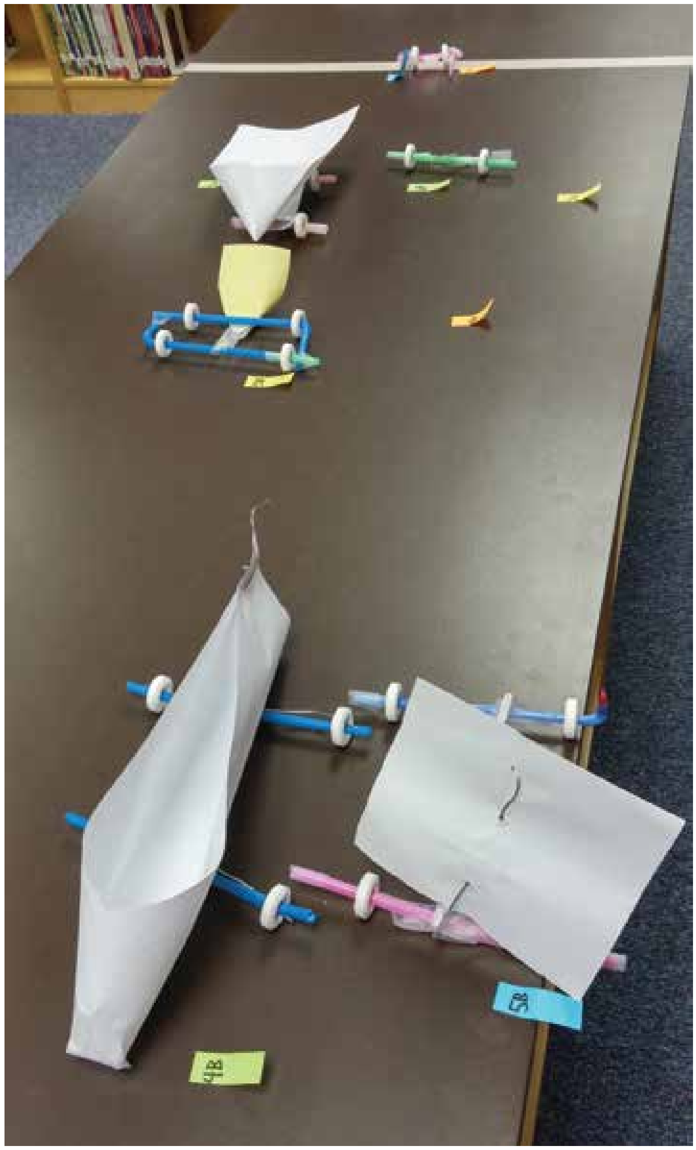
Reverse

- What would happen if you reversed this process or sequenced things differently?
- What if you try to do the exact opposite of what you're trying to do now?
- What components could you substitute to change the order of this product?
- What roles could you reverse or swap?
- How could you reorganize this product?

SCAMPER brainstorming tool (see Figure 2). Developed by Bob Eberle, SCAMPER is an acronym that stands for the words Substitute, Combine, Adapt, Modify/Minify, Put to Another Use, Eliminate, and Reverse. SCAMPER is essentially a cognitive strategy that serves as a scaffold (Palincsar and Brown 1984).

During instruction, there are often times when we want students to solve a problem or a task. Cognitive strategies are those tools that provide students with a structure for learning when a task cannot be completed through a series of steps. In moving students through the redesign phase of their car, there really wasn't a set of steps we could take them through. Because each car was designed differently, we had to find a tool that would work for all students and be applicable to their car designs. The SCAMPER brainstorming tool was the perfect cognitive strategy or scaffold (Rosenshine 1997) to use because it provided students with a set of questions they could "think" through when examining their own design.

To teach students the tool, we did not start with their car but rather with an object they were familiar with using each day—a toothbrush. This was done intentionally because we wanted students to focus on learning the tool without having to learn the tool and think about their new design. For example, in redesigning a better toothbrush, we asked students to think through the questions associated with Substitution. Could they substitute a different material in place of the material used in the original design that might make the toothbrush more effective or easier to use? Could they combine something in the design? As we explained to students, the questions were merely tools to help them think in different ways (Figure 2 includes the words and associated questions). Students worked in collaborative groups and worked with their teacher, Mrs. Sawyer, to go through each letter to rethink the design of their toothbrushes. When they were finished, students shared their ideas with the entire class.



Car testing

Extend: Designing and Testing

Once we felt like students understood the strategy, we then had them go back to their original car designs. Using the SCAMPER method, students took what they did during the first week and redesigned their vehicles by answering certain questions and marking what they changed. Beginning with the vehicles themselves, the designs were as different as the children who built them. In fact, even with the children working with other students at their tables, no two "airmobiles" were alike. Many had a four-wheel design, similar to that of a car, but others resembled more of a sailboat or airplane. Designs included between two and eight wheels. Most used straws to build a sort of chassis for their vehicle, but a few used paper clips as their structural base. Shapes of the designs were varied; there were triangular, rectangular, and square designs. Some students made 3-D shapes like a rectangular prism or square pyramid. Still others built aspects of their vehicles from origami shapes (Figure 3, p. 40, shows a variety of car designs).

Students used the prior knowledge of wind-powered vehicles as the basis for their projects. Many of the vehicles were built with a design that resembled a sailboat with wheels. Some featured wings similar to a biplane. Still others featured a kite-inspired design with cross-supports and a piece of paper stretched over the frame. In an effort to catch the wind and force their vehicle to move, many of the vehicles featured a sail (triangular or

FIGURE 3.

A variety of cars designed by students.

rectangular). Others included a parachute design that students believed would allow the air to fill in the chute and cause the vehicle to move. Ultimately, they saw how the tiny things they altered on their vehicles led to some interesting and sometimes incredibly different results in distance and speed.

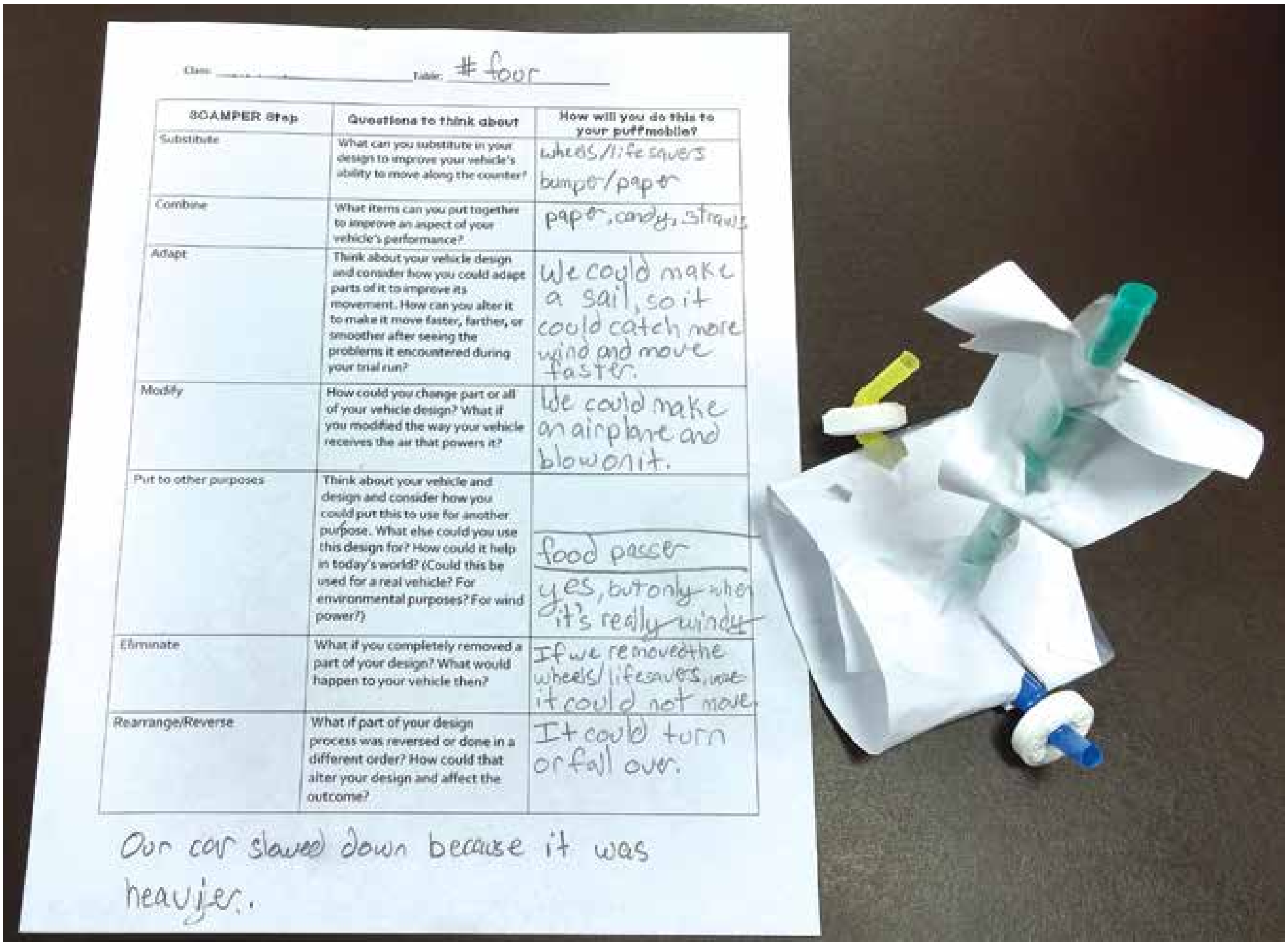
Evaluate: Lessons Learned

It was amazing to see how students worked through this design challenge. Students worked together, and in some cases, students who never wanted to work with anyone else were jumping in to provide support and ideas to their classmates. Waiting to test their designs did not matter; students were just as excited to see how their classmates' redesigns worked as they were to test their own cars. The students watched their classmates' airmobiles and paid attention to how each design worked. They rarely spoke, except when encouraging each other or in making note of how something responded to the air.

"Did you see how the car turned sideways? I don't think it was supposed to do that, but it really went far!" noted one of the boys. "I think I'm gonna try a rectangle sail if my triangle one doesn't work after my first run." The children were so interested in the designs that they couldn't wait to get back to their tables and see how to improve them!

Using the SCAMPER process, one student rebuilt her vehicle "like a hovercraft." The wheels, rather than being attached to roll, were attached to the bottom of straws to remain flat on the surface of the table. A sail-like device was then attached to allow the vehicle to move as the candy "wheels" glided along the smooth table, rather than rolling on an axel. The student said she did this because the tape she had originally used to attach the wheels to an axel "got in the way of it moving. The wheels couldn't roll well because they kept getting stuck. Then a wheel would quit turning and my car would blow sideways and fall off the table." She found that, after reengineering her vehicle, her distance more than doubled.

Another girl in one of the fourth-grade classes was not immediately interested in participating, and instead made origami flowers with straws as the stems. Rather than redirecting her, we chose to let her continue folding her paper as her table mates worked feverishly to design their vehicles and see what happened. She had made four of the flowers and held them together in a bouquet, when someone noted to her that the straws came together like they were part of a car frame. She decided to see if she could indeed use her flowers to make a vehicle. She taped the four straws together at the end and then attached a wheel to the point using a paper clip. After taping the flowers together, she discovered she had accidentally created a



The SCAMPER steps required students to thoughtfully analyze their designs.

wind-powered vehicle with a car frame that resembled a Formula One design. Her vehicle not only went far but also straight. After her first trial, she was immediately hooked and went back to her table to see how she could improve her car to go even farther. She was so excited to discover her accidental success in engineering!

Students found unexpected successes as they designed and redesigned throughout the SCAMPER process. One child had made an origami "puff box," believing that as he blew on the side of the box with the hole, his breath would cause the box to inflate and fill up with air, thus catching his wind and moving along the table. What he discovered, however, was that blowing from a distance onto his box did not cause it to inflate. Instead, he found that his breath was caught on the un-inflated side of the box, causing his vehicle to move sideways. He used SCAMPER and bent some of the origami folds and flaps out, and as a result, he discovered his car was able to go farther in distance and straighter as it moved.

Assessing Student Thinking

Often during learning experiences such as the SCAMPER lesson, it is not necessary to do a formal assessment. Our goal with the assessment tied to this lesson was to see the student's thinking and identify any questions they still had in their minds. To quickly assess, we like to use the strategy known as 3-2-1. Students reflected on the three things they learned through the design process; two things they still had questions about with regard to changing their design, and one thing they felt really good about during the experience. This assessment was done after week one and again after the introduction of the SCAMPER strategy. When the students came back to the library, we were able to address the questions provided to us by the students.

While we chose to keep our assessments less formal, it would be very simple to provide more formal assessment opportunities for students using this unit. For instance, students could be asked to set a goal for the distance their car would move, then document the step-by-step process in reaching this goal. Students could also be required to do a set number of trials and graph the distance moved by their car during each trial. Writing a detailed analysis of the design and movement of their car would provide students with an opportunity to write an analytical paper as part of a cross-curricular lesson. Finally, using photographic evidence of each step in the process, students could use their own pictures in a computer presentation of their project, thus integrating technology into this unit as well.

We discovered so many things in completing this series of lessons with our students. First, and perhaps most important, we found that in allowing the children to design and build their vehicles as they saw fit, we not only captured their attention but also their intrigue. Even the most reluctant students finally jumped on the bandwagon and got hooked. They had the freedom to explore; their only limit was what they set for themselves. It was fascinating to watch the children try and SCAMPER and enthusiastically redesign their vehicles before returning to the counter for another trial.

We also noticed that the children took notes, answered questions, made observations, and shared their qualitative data eagerly. Sharing the changes made to their car designs and what resulted from those changes was a constant topic of discussion. For instance, students noted that the Lifesaver wheels would not stay on their vehicle, so they shared with their peers how an axle was made using a paper clip. Another student then shared how he had made an axle and added tiny little pieces of tape to serve as a sort of lug nut to prevent the wheels from moving along the axle as the vehicle moved. They didn't feel that they were working because there was an aspect of play in their work. Allowing them to manipulate their materials based on their own observations put them in control. They really were the scientists and engineers. They were instructing themselves. They activated prior knowledge, sought advice and suggestions from classmates, and returned to their work with electricity that you could almost feel.

By the end of the lessons, the students wanted more. Many of the children went home, worked on their designs there, and brought their redesigned air mobiles back in on their own time for a trial run in the library. They did research online, bringing in printouts of engineering sites and air-powered machinery to show us. Many of them shared how they had gotten parents involved to figure out how best to manipulate their vehicles for optimum performance.

What started as a simple way to introduce students to engineering turned into so much more for us and for our students. Their understanding and application of the terms they had learned in their science unit were being transferred to their design challenge. Graphing went from a chore to a competition as they saw which classmates' vehicles went the farthest along the counter. Students even started talking about the SCAMPER tool in their classrooms. With just one simple lesson in a library, learning had more meaning than we had ever imagined! ■

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NSTA Connection

Visit *www.nsta.org/SC1509* for a blank version of the SCAMPER brainstorming sheet.

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

3-PS2-1 Physical Science and 3-5-ETS1-1

www.nextgenscience.org/3-ps2-1-motion-and-stability-forces-and-interactions
www.nextgenscience.org/3-5-ets1-1-engineering-design

The materials/lessons/activities outlined in this article are just one step toward reaching the performance expectations listed below. Additional supporting materials/lessons/activities will be required.

Performance Expectations	Connections to Classroom Activity
3-5-ETS1-1 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.	Students build a car using a set of materials (four Lifesavers candies, two straws, two paper clips, scissors, tape, and a sheet of paper) and then redesign the car based on data collected.
3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.	Students were instructed to build a car of their own design that would move with a puff of air. Students were not told how to build the car, but to design and redesign a car until it moved as they desired.
3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.	Students used the SCAMPER brainstorming tool to redesign their cars.
Science and Engineering Practices	
Developing and Using Models Using Mathematics and Computational Thinking	Students: • construct models of cars that are able to be moved by air. • use observations (and discussions) to redesign car so it is able to move farther with air.
Disciplinary Core Ideas	
ETS1.C: Optimizing the Design Solution • Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.	Students build, test, and refine a car propelled by air.
PS2.A: Forces and Motion • Each force acts on one particular object and has both strength and direction. • The pattern of an object's motion in various situations can be measured and observed.	Students design a car that is moved by air. Students redesign car in order to have it travel farther using air.
Crosscutting Concept	
Patterns	Students use patterns of motion to predict future motion.

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