LESSON 9

Designing and Building a Vehicle with a Sail

Overview and Objectives

Having examined the ways in which friction affects the motion of an axle-driven vehicle, students are ready to apply their knowledge of friction to a new situation—studying the effects of air resistance on a vehicle's motion. To prepare for this study, each group uses design process skills to modify its axle-driven vehicle to hold a sail. By discussing their initial observations, students prepare for Lesson 10, in which they conduct a formal investigation to test how air pushing against the sail affects their vehicles' motion.

- Students brainstorm how a sail might affect the motion of their axle-driven vehicles.
- Students adapt their vehicles to hold a cardboard sail.
- Students make initial observations about the influence of the sail on the vehicles' motion and discuss these observations.
- Students reflect on their work by completing a self-assessment.

Background

In this lesson, students modify their axle-driven vehicles by adding a cardboard sail. Because there is no best solution to this new design challenge, the lesson encourages diverse approaches and outcomes. Students can learn from each other while they work in their own groups and watch others. It is important to emphasize that an essential part of the design process is evaluating and refining the product. Like engineers, students must repeatedly refine their vehicles, test them, and record results to keep track of the effects of each new change.

In brainstorming how a sail might affect a vehicle's motion, it is important to review the ways in which students moved their vehicles both faster and slower in earlier lessons. To make their vehicles go faster, students may have done the following:

- Increased the force when pulling the vehicle with a weighted string by increasing the number of washers (Lesson 3).
- Decreased the resistance to motion by reducing the vehicle's load (Lesson 4).
- Increased the amount of energy stored in the vehicle by increasing the number of turns of the rubber band around the axle (Lesson 7).
- Minimized friction by placing tan hub connectors and crossbars on their vehicle to reduce the rubbing of wheels on the frame (Lesson 8).

To make their vehicles go slower, students may have done the following:

- Decreased the force when pulling the vehicle with the weighted string by decreasing the number of washers (Lesson 3).
- Increased the resistance to motion by increasing the vehicle's load with additional building pieces or blocks of wood (Lessons 4 and 5).
- Decreased the amount of energy stored in the vehicle by decreasing the number of turns of the rubber band around the axle (Lesson 7).
- Increased friction by removing the tan hub connectors between the axles, frame, and wheels (Lesson 8).

Most students' familiarity with sails will focus on sailboats, in which a sail catches the wind and moves the boat. A sail, however, can also slow a vehicle down. When the wind is too strong or blowing in the wrong direction, a sailor will furl, or fold, the sail, so the wind does not push against the sail. When students add a cardboard sail to their vehicles in this lesson, they will probably make preliminary observations about the sail and its effect on the vehicles' motion. They might notice that their vehicle does not move as far as it did in Lesson 7.

In this lesson, students complete a self-assessment. Do not grade it. Its purpose is to help you assess each student's attitudes about the unit and evaluate how each group is working so you can consider regrouping if necessary. It will also help you identify students' concerns and misconceptions so that you can address them before the unit's end.

Materials

For each student

1 science notebook
1 copy of **Student Self-Assessment A**
Safety goggles

For each group of three students

1 standard vehicle
1 bucket of building pieces
1 piece of cardboard, 23 × 30 cm (9 × 12 in)
3 No. 16 rubber bands, connected
1 set of colored pencils
1 metric ruler
1 circle template

For the class

Brainstorming list, "What Made Our Vehicles Move Slowly and What Made Our Vehicles Move Fast" (from Lesson 5)
Assorted colored markers
Masking tape
2 single-hole punches (optional)
Trade books or advertisements that show vehicles with sails

Preparation

1. Make a copy of **Student Self-Assessment A** for each student.
2. Check the connected rubber bands. If they have become less elastic, replace them.

3. Display the brainstorming list from Lesson 5. Set out the colored markers.
4. Collect trade books or advertisements that show vehicles with sails. Display the trade books for students to use when designing their vehicles or to look at in their spare time.
5. Check the vehicles to make certain they are in their standard form. If some are not, have a member from each group modify its vehicle before beginning the lesson (see Lesson 2, pg. 7).
6. Arrange the vehicles and materials at the distribution center. You may want to set out one or more single-hole punches and rolls of masking tape for groups that have difficulty attaching the sail. Or cut a 30-cm (12-in) strip of masking tape for each group and hang the strips along one end of the distribution table.

Procedure

1. Direct students' attention to the brainstorming list from Lesson 5. Encourage them to suggest any new ideas they have about what might cause their vehicles to move slowly or fast. Use a marker of a different color to add their new ideas to the list.
2. Have students hypothesize what influences a sail might have if it were fastened to their vehicles. Use another colored marker to add these ideas to the brainstorming list. (If students do not mention it, encourage them to discuss how the sail might affect the vehicle's motion when moving *with* the wind and *against* it. Also ask students if the sail would have any effect on the motion of the vehicle if there were no wind.)
3. Let students know they will adapt their standard vehicles to hold an upright piece of cardboard—like a sail—that will catch the air. Students may want to sketch their designs in their notebooks before building and use the trade books to research possible designs. They should use the entire piece of cardboard. Two sample vehicles are shown in Figure 9-1.
4. After students discuss their plans with the group, have each group get its bucket of building pieces, vehicle, connected rubber bands, and piece of cardboard. After students attach the cardboard sail to their standard vehicles, ask them to return the buckets to the distribution center.

Management Tip: Some groups may have difficulty attaching the cardboard sail in an upright position to their vehicle. If they request assistance, suggest that they use masking tape or punch two or three holes in the sail. Students can insert rods through the holes, which will facilitate fastening the sail. Make these suggestions only if groups have attempted their own design and have not succeeded.

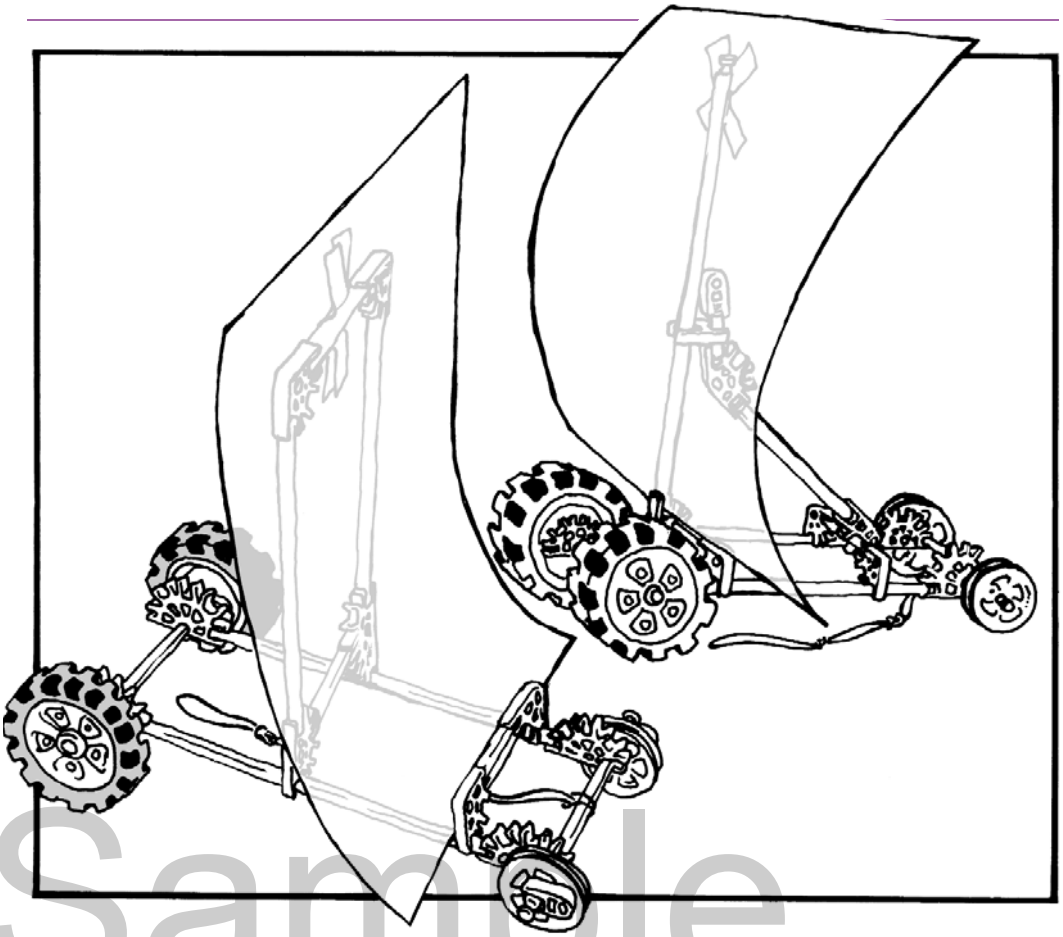
Final Activities

1. Ask students to discuss how they completed the design challenge. What successes did they have? What problems did they encounter? How did they solve them?
2. Ask students to **hypothesize,** or make an educated guess about, how the sail might affect the vehicle's motion when the sail is pushing against the air. Let students know they will test their hypotheses in Lesson 10.
3. Have students clean up by carefully placing their vehicles with the attached sail on the distribution center. Students can label their vehicles with tape.

Management Tip: Students can complete the following steps now or at another more convenient time before Lesson 11.

Figure 9-1

Sample student vehicles with a sail



4. Prepare students for **Student Self-Assessment A** by asking them to think about and share with the class what they have learned thus far in the unit.
5. Distribute one copy of the self-assessment to each student. Review each question, but do not elaborate on possible answers. Remind students that this is not a test. It is a way to help them reflect on what they have learned.
6. Have students complete **Student Self-Assessment A** independently. When they are finished, collect the assessments or have students place them in the pockets of their science notebooks. Let students know they will revisit the self-assessment at the end of the unit. (See Figure 9-2 for student examples.)

Extensions

LANGUAGE ARTS SOCIAL STUDIES SCIENCE

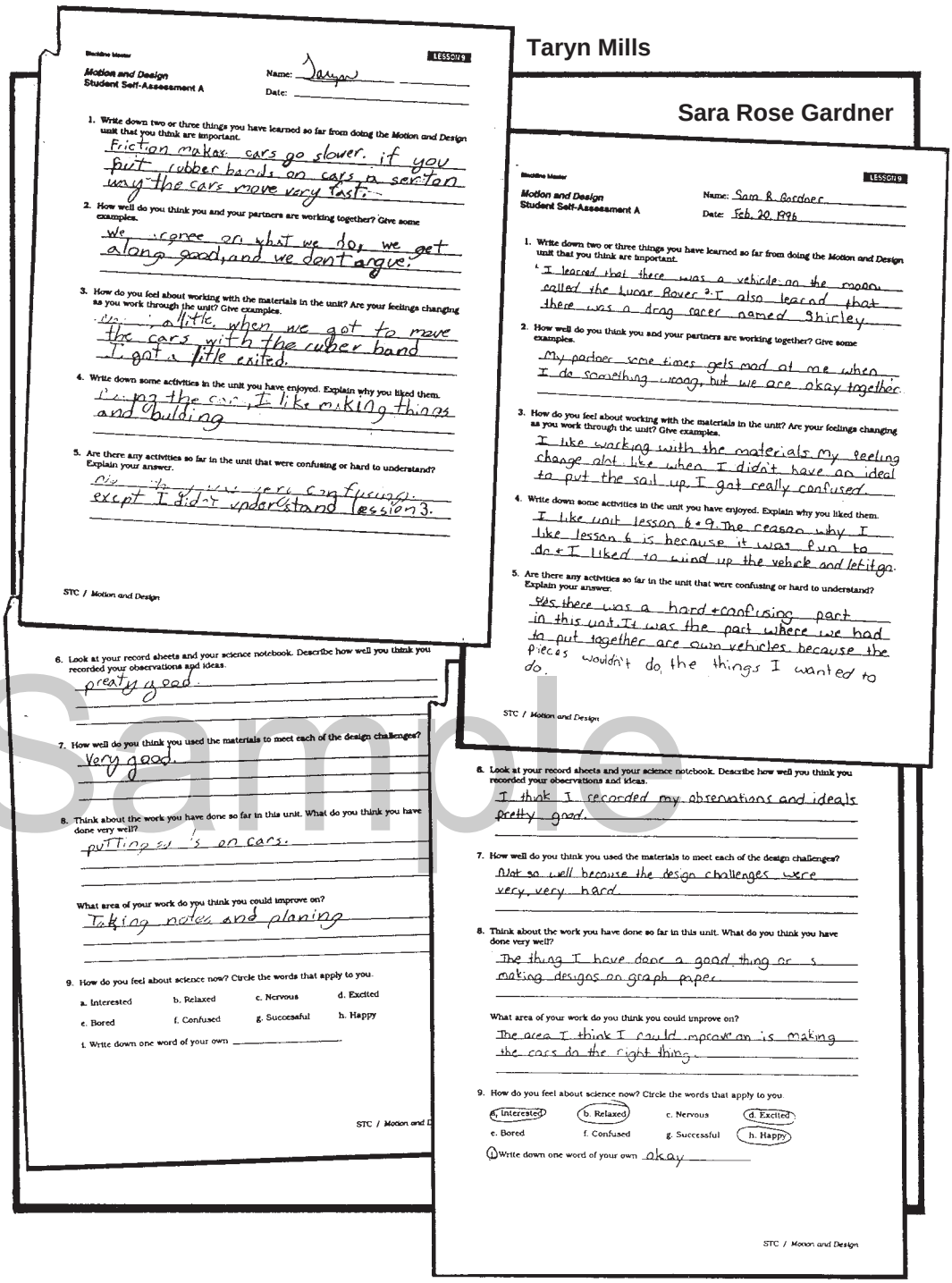
1. Ask students to bring kites of various shapes to school. They can observe how each kite flies on a windy day. Why do the kites fly? Why do some kites fly better than others? Students can also design, build, and test their own kites. Ask students to research the history of the kite. When was it first used? How has it changed over the years?

SOCIAL STUDIES LANGUAGE ARTS

2. Encourage students to research the history of the sailboat. How has its design changed over the years? How has the use of sails changed? When is a sail a hindrance to the boat's forward motion?

Figure 9-2

Sample Student Self-Assessment A



SCIENCE MATHEMATICS

3. Students can use an electric fan or a mounted blow dryer to simulate moving a sail-driven vehicle with wind energy. Have them mark the distances their vehicles travel at various wind speeds (different speeds on the fan or blow dryer) and then measure the distances and graph the results.

Assessment

In this lesson, students completed **Student Self-Assessment A.** You will administer a matching self-assessment at the close of the unit. Compare students' responses on the two assessments to determine areas of growth.

Preparation for Lesson 10

- Students will use their vehicles with a sail in Lesson 10. Make certain they do not disassemble or modify the vehicles between lessons.
- The investigation in Lesson 10 requires a large floor space. If you have access to a resource room, gym, or cafeteria, reserve it ahead of time.

Motion and Design
Student Self-Assessment A

Name: _____

Date: _____

Motion and Design
Student Self-Assessment A, *continued*

Name: _____

6. Look at your record sheets and your science notebook. Describe how well you think you recorded your observations and ideas.

_____

_____

_____

7. How well do you think you used the materials to meet each of the design challenges?

_____

_____

_____

8. Think about the work you have done so far in this unit. What do you think you have done very well?

_____

_____

_____

In what area of your work do you think you could improve?

_____

_____

_____

9. How do you feel about science now? Circle the words that apply to you.

a. Interested b. Relaxed c. Nervous d. Excited

e. Bored f. Confused g. Successful h. Happy

i. Write down one word of your own _____