Assignment Discovery Lesson Plan
Junkyard Wars: Mechanical Monsters

Subject
Physical Science

Grade level
6 – 12

Duration
Two or three class periods

Objectives
Students will
- design and build a Lego car that can ascend the steepest slope possible;
- present and demonstrate their vehicles in class; and
- explain briefly how they optimized them.

Materials
- Lego parts
- Lego motors
- Wood, cardboard, poster board, or flexible plastic (to construct board with incrementally increasing angle)
- Notebooks or paper (for logging ideas and tests)

Procedures
1. Gather Lego parts or motors. Ask students for donations (for extra credit, if you'd like). It's amazing how much they have of their childhood toys. Or you can try to collect materials from garage sales, ask toy-store managers for donations, or write a small grant to purchase the materials initially. Fortunately, they can be reused many times.

2. Make a board with an increasing slope for students to test their cars on. You can use wood or cardboard with flexible pieces like poster board between the different angle sections to create an incrementally increasing angle. Or you could make the whole thing out of a curved piece of flexible plastic for a constantly increasing angle.

3. Tell students their challenge is to build a Lego car that can ascend the steepest slope possible. Give them the following rules, along with any additional ones you'd like to specify:

- The board your car must ascend starts out at a shallow slope and gradually increases the slope. This continues until your vehicle fails in some way (stops moving or tips over).
- You may not do anything that changes or damages the board, including using anything on your wheels that would mar or leave residue on the board, such as nails, glue, sticky notes, or tape.
- Different types of Lego motors are available. You may use up to two motors in your vehicle. Because the motors are a shared resource, make them easy to attach and remove from your vehicle.
- You may not interact with the top of the board (grappling hook or similar tool) or the outside world (walls or sprinkler pipes). Your vehicle may interact with the edge of the board.

4. Give students the following questions, designed to help them consider, design, and calculate:
    - What are the different ways your vehicle could fail—that is, stop climbing the slope? (Tip over, stall the motor—not enough torque—or slide back down the hill.)
    - How can you prevent each of these? Be specific.
    - What does this tell you about how you design the car? (Where the mass is, whether you want big or small wheels, how many gears to use, etc.)
    - Do you want to use the plain motors or the gear motors (the funny-shaped ones)? Why?
    - Which wheels do you want to use? Why?
    - Are there other ways to increase and decrease quantities you care about (friction, normal force, mass, wheel radius, gear ratio, etc.)? Which of these actually makes a difference?

5. Students should keep a log of their design ideas, physics research and testing, and the results of modifications they make to their vehicles.

6. Have students present their vehicles and demonstrate them in class. Ask them to explain briefly how they optimized their Lego cars.

Evaluation

Use the following three-point rubric to evaluate students' work during this lesson.

- **Three points:** Students completed their physics research carefully and thoroughly; made highly creative and functional climbing cars; kept detailed logs of their research and testing; made informed modifications to their vehicles.
- **Two points:** Students completed their physics research somewhat thoroughly; made functional climbing cars; kept inconsistent logs of their research and testing; made some informed modifications to their vehicles.
- **One point:** Students completed no real physics research; made cars with little climbing ability and no functional modifications; kept poor logs of their research and testing.

Vocabulary

force

Definition: A “push” or “pull” that changes the motion, size, or shape of a body

Context: Force is a vector quality that tends to produce an acceleration of a body in the direction of its application.

friction
Definition: A resistive force that tends to slow or stop motion
Context: Along with moving your Lego car, the wheels are also a source of friction.

gear ratio
Definition: The ratio of the speed of rotation of the powered gear of a gear train (motor) to that of the final or driven gear (wheel); how many revolutions of input are needed to produce one revolution of output
Context: If your car has a gear ration of 5:1, it means that the wheels turn once for every five turns the motor makes.

mass
Definition: The intrinsic quantity of matter in a body regardless of its volume or of any forces acting on it; an object's resistance to changes in speed or direction of its motion
Context: The greater the mass of your car, the greater the strain on acceleration.

wheel radius
Definition: Measurement of tire size that measures from the center point to the outer edge
Context: The wheel radius of your Lego car may be best measured in centimeters.

Academic Standards

The National Science Education Standards provide guidelines for teaching science as well as a coherent vision of what it means to be scientifically literate for students in grades K–12. To view the standards, visit http://books.nap.edu.

This lesson plan addresses the following science standards for grades 5–8:

- Science as Inquiry: Abilities necessary to do scientific inquiry, Understanding about scientific inquiry
- Physical Science: Motions and forces, Transfer of energy
- Science and Technology: Abilities of technological design, Understandings about science and technology

This lesson plan addresses the following science standards for grades 9–12:

- Science as Inquiry: Abilities necessary to do scientific inquiry, Understanding about scientific inquiry
- Physical Science: Motions and forces, Interactions of energy and matter
- Science and Technology: Abilities of technological design, Understandings about science and technology

Credit

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(Adapted from Eric Smith, Ben Davis, and Alexis Cavic of the Massachusetts Institute of Technology, who originally developed this project)