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University of California Berkeley
Applied Design Engineering Project Teams (ADEPT)

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Speed Control Cars

Objective/Purpose:
Students will build a motor driven car with speed control in order to gain a practical understanding of the speed equation; v = d/t. Students will utilize tables, graphs, equations and words to explain the relationship between their real-world measurements and data to the position of a potentiometer and the speed of their motion car.

Topic:
Speed, speed equation, and graphing.
Related engineering applications: Engineering design, control engineering.

Grade Level: 7-9

Pre-Requisites:
Use of Equations
- Knowledge of a basic form of the distance equation: $d = X_f - X_i$
- Knowledge of the basic form of the speed equation: speed = d/t

Graphing skills
- Labeling axes
- Independent and dependent variables
- Numbering axes constantly
- Locating coordinates
- Creating best fit lines for linear relationships

Inquiry Skills
- Knowledge of a fair experimental test.

Prep—Time: 60-90 minutes

Lesson Time: 150-200 minutes

Material List:

Per Student—
- Scissors
- Graph paper
- Data and Questions worksheet

Per Group—
- Design Worksheet
- Building instructions
- 0.5 ft^2 cardboard
- Drinking straw
- 7" craft wire
- 2 ft. masking tape
- Measuring tape or yardstick
- Stopwatch
- Car shape templates (optional)
- Thumbtack (optional)

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Quick Lesson Summary:

Prior to class:
- Prepare building materials and workspace
- Build Motor Units
- Build sample car bodies

Initiating class:
- Introduce "Engineering Design"
- Show sample cars
- Select groups

Construction activities:
- Groups select a design
- Groups build a car body
- Groups test car body with a motor
- Groups repeat building process or modify design until car moves.

Speed Testing:
- Students measure maximum speed
- Students measure speed vs. potentiometer setting.
- Groups attempt to match a target speed using their measurements.

Material List: (continued)

Per Motor Unit (each used by one group per class)

- 0.5 ft^2 cardboard
- 1 or 2 wood craft circles with a 1/16 inch hole in center
- 3" x 3" x 3/8" balsa wood square.
- 12 V hobby motor
- 9 V battery
- 9 V battery clip
- 25-Ohm Rheostat or variable resistor
- 3 ft. masking tape
- Glue
- Potentiometer label (see potentiometer_label.ppt)

Tools:

- Drill and 1/16" drill bit
- Exacto-knife or hacksaw for cutting balsa wood
- (Optional) Soldering iron and solder.
- (Optional) Circle cutter

Lesson Process:

Preparation For The Lesson

Prior to class:

1. Cut or buy cardboard circles for use as front wheels. A circle cutter, available at many craft stores, makes it reasonably efficient to produce a large number of wheels of various sizes from posterboard.
2. Cut craft wire into 7 inch lengths.
3. Drill holes in the center of wooden circles for attachment to motors, using a 1/16" drill bit. Again, most craft stores sell thin wooden disks, with 1" to 1 ¾" disks being most suitable for this project.
4. Print potentiometer labels, shown in Potentiometer_label.ppt
5. Select one or more testing locations and mark a specified distance with tape or other marker. A smooth surface is recommended, with a testing distance of 150 to 200 cm.

NOTE: Prior to class or with small groups of selected students and before beginning the module with the general class; students may be selected based on ability to follow instructions and work individually, as well as grasp of material:

6. Build motor units (see SCC_Motor_Unit_Build_Instructions)
7. Build sample front of a car. If working with a small group of students, let these students design their own fronts for the car, and use these as templates for students in the class at large.

✍ Initiating The Class

1. Show sample car to class, explain that students will be able to:
   a. Design their own cars and use the speed equation to measure their motion.
   b. Change the speed of the car.
   c. Set the car to specific speeds.

2. Introduce the idea of the engineering design process. In simple form:
   a. Identifying the problem to solve
   b. Generating ideas
   c. Analyzing choices
   d. Prototyping
   (see SCC_Intro_Overhead.ppt).

3. Under the idea of "Defining the Problem," briefly introduce ideas of "goals" and "constraints". Refer to the Intro Overhead and the Design Worksheet (SCC_Design_Worksheet.doc)

4. Separate the class into groups of three to four students.

Procedures For Session I: Construction

Part I: Selecting a design (~10 min)

Vocabulary:

- ✍ *Average Speed*
- ✍ *Speed*
- ✍ *Engineering Design Process*
- ✍ *Constraint*
- ✍ *Specification*
- ✍ *Prototype*
- ✍ *Potentiometer*
- ✍ *(optional) Voltage*
- ✍ *(optional) Resistance*
- ✍ *(optional) Acceleration*

CA Science and Math Standards:

Grade 8: Science Standards
Velocity of an object
1.B Average speed is the total distance traveled divided by the total time elapsed. The speed of an object along the path traveled can vary.
1.C Solve problems involving distance, time, and average speed.

Investigation and Experimentation
1.B Evaluate the accuracy and reproducibility of data.
1.C Distinguish between variable and controlled parameters in a test.
1.D Recognize the slope of the linear graph as the constant in the relationship y=kx and apply this to interpret graphs constructed from data.
1.E Construct appropriate graphs from data and develop quantitative statements about the relationships between variables.
1.G Distinguish between linear and nonlinear relationships on a graph of data.

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1. Show students their design choices. Several design choices are available in SCC_Design_Choices.ppt and are compiled on one sheet in SCC_Design_Choice_Overhead.ppt. Alternatively, small groups of students may build cars ahead of full class instruction, in which case their designs could become the design choices for the class.

2. Ask each group to think about what shape car body and what size wheels they want their car to use (choices shown in SCC_design_choice_overhead.ppt).

3. Instruct each group to select a body design, wheel size, number of wheels to use, and to complete parts I & II of their Design Worksheet (SCC_Design_Worksheet).

Part 2: Building the car body (20 min)

1. Pause the class to review building procedure. Announce to the class that it is time to settle on their designs. Describe how the wheel and axle assemblies are built. Use a larger model, such as a pipe cleaner or bicycle handlebars, to show how a wire can be bent to hold wheels straight.

2. Distribute building instructions (SCC_Student_Build_Instructions.doc) to each student and ask a representative from each group to pick up building materials.

3. Direct students to refer to their building instructions to build the front of their car. Remind them that a motor will be added when they complete the body.

CA Science and Math Standards:

Algebra 1:

6.0 Students graph a linear equation and compute the *x*- and *y*- intercepts (e.g., graph $2x + 6y = 4$). They are also able to sketch the region defined by linear inequality (e.g., they sketch the region defined by $2x + 6y < 4$).

7.0 Students verify that a point lies on a line, given an equation of the line. Students are able to derive linear equations by using the point-slope formula.

18.0 Students determine whether a relation defined by a graph, a set of ordered pairs, or a symbolic expression is a function and justify the conclusion.

Part 3: First Test

1. When the first group finishes the front of its car, halt the class briefly to explain the motor units. Tell students that they should be getting ready to test, and demonstrate how to turn the motor on. Give motor units to groups as they complete the fronts of their cars.

2. Most groups will need time to make their car move once given the motor, usually due to quality of construction. Circulate through the class, helping students move from their initial car body to a car that moves with the motor.

3. Once some groups have working cars, challenge them to produce the fastest time of the day. Distribute stopwatches and ask students to calculate the maximum speed of their cars. This is largely autonomous, with more formal measurements happening later.

Part 4: Clean-up and Review

1. With about 10 minutes left in class, have students begin cleaning up their workspaces.

2. Instruct students to fill out parts III and IV of their Design Worksheet when they finish cleaning up.

3. Before dismissing class or as a homework assignment, ask for or call on students to review their experience. Suggested questions:
    a. What was one thing you would improve if you could?
    b. What was one problem with your car that you fixed?
    c. What was one especially good thing about your car design?

Part 5 or as a 2nd Session:

1. Describe the speed measurement task to the class (i.e. Set the potentiometer, take several time measurements to cross a fixed distance as that setting, then move to the next setting). Call on students to restate instructions, to check that measuring times at different settings of the potentiometer is understood.

2. If a separate class is used for construction and testing, provide students with 5-10 minutes to make sure that their car is still working and make any last minute changes.

3. Distribute a Results Worksheet (SCC_Results_worksheet.doc) to each member of the class and a stopwatch to each group.

4. Have students measure and record the time required to travel between reference points at each potentiometer setting. This will probably require 20-30 minutes.

    NOTE: In most cars tested to date, the motor does not have enough power to move the car at the lowest setting, and data may be omitted for that setting.

5. On their results worksheet, students should calculate average time for 3-5 trials on each potentiometer setting.

Part 6: Graphs and Understanding

6. Instruct groups to set aside their cars when they finish taking data. Explain that they don't want their car to be damaged or altered before the contest to match a selected speed using their graphs.

7. Introduce Results Worksheet, part 2: students should create distance vs. time graphs for each potentiometer setting, using their measurement distance (marked out prior to class) and average times. Review how to calculate an average time, if necessary

8. Allow 15-20 minutes for completion of the Results Worksheet, part 2.

9. Introduce Results Worksheet, part 3: students should calculate average speed at each potentiometer setting. Review how to calculate average speed, if necessary

10. Allow 5-10 minutes for average speed calculations.

11. Results Worksheet, part 4: students should graph average speed versus potentiometer setting. Emphasize that students are graphing average *speed*, not average *time*.

12. Allow 10-15 minutes for graphing

Part III: Controlling Speed

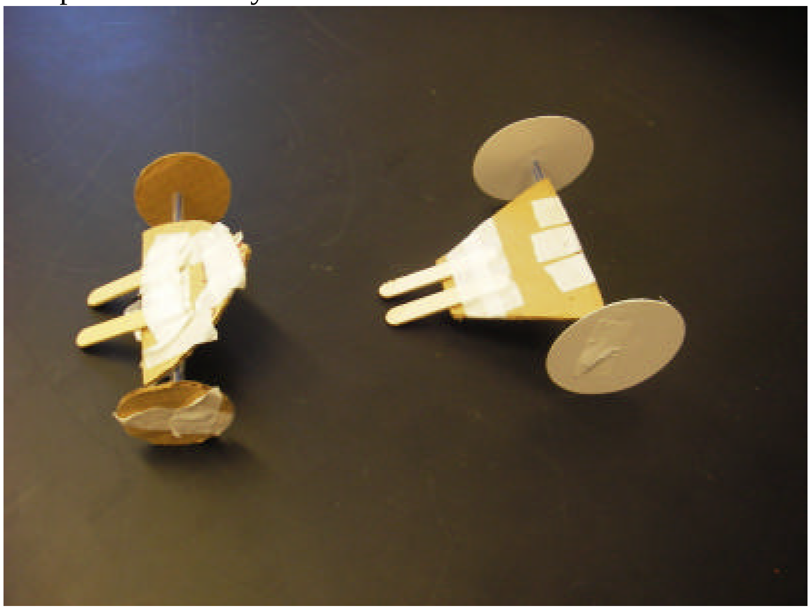
1. Announce a target speed to the class, within the range of motor speed (20-30 cm/s is a good range to select the target speed from, as most cars tested to date have speed ranges overlapping that range).

2. Instruct students to use their graph to predict the setting required to achieve the target speed. Give each group one chance to hit the target, *without* any tests beforehand.

Reflection

1. Students should think about
    a. What worked and what didn't work in designing their car
    b. How they learned to improve the car (see design worksheets).
2. Students should describe how they decided to set their cars at a certain speed using their graphs (see results worksheet)
3. Assessment questions, focused on making and interpreting graphs, are available in SCC_Assessment.doc

Sample car bodies by students



Sample motor unit