Note to the Teacher

In this investigation students will identify the relationship between the diameter of the wheel and the speed the robot travels. This investigation gives the teacher an excellent opportunity to:

1. Teach scientific process

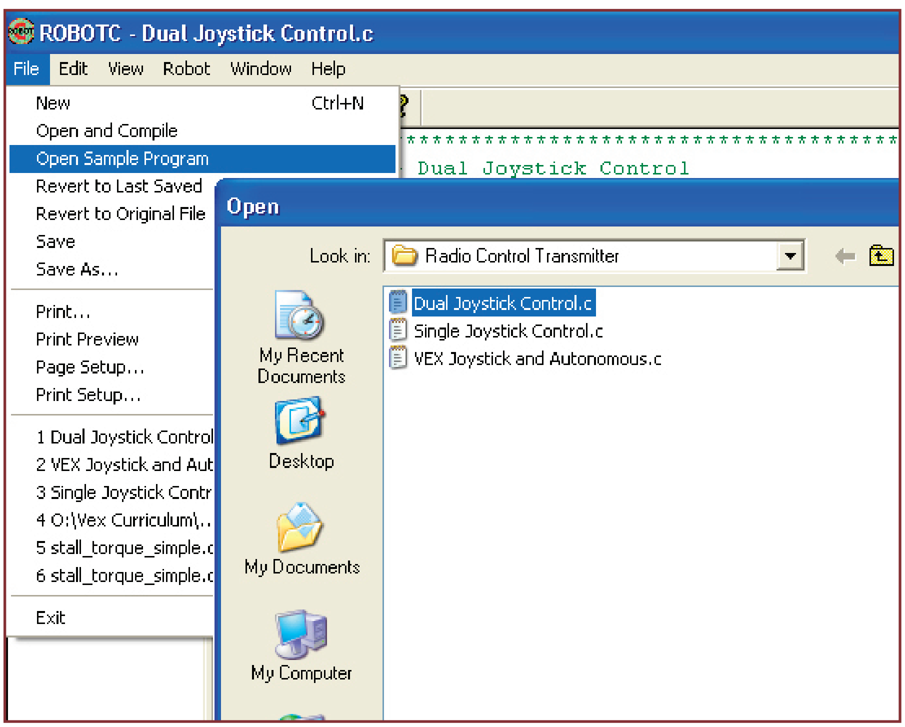
2. Apply measurement

3. Talk about and use mathematical terms such as “plot (or graph) data”, and “extrapolate”. In mathematics, extrapolate means to estimate a value of a variable outside a known range from values within a known range by assuming that the estimated value follows logically from the known values.

Students will construct a robot that can be modified to incorporate three different driving wheel conditions: the small wheel, the medium size wheel, and the large wheel. Students will be given a robot, a stop watch, and a specific distance to travel. The distance will be marked by a piece of tape at the beginning and the end of the testing area. The robot will use the default code on the VEX controller and the VEX radio to complete this investigation. Students are required to calculate the speed the robot travels in condition one, estimate the speed for condition two, and extrapolate the speed for the third condition from the plot of the first two conditions. Students will write a conclusion about what they learned.

Please note

If you have ever downloaded ROBOTC firmware (or programs), you will now have to download a ROBOTC sample program, “Dual Joystick Control.” Alternately, you can re-download the Vex Default Firmware.



• Select File/Open Sample Program
• Browse to Radio Control Transmitter/Dual Joystick Control and download it.
• Turn the robot on and off. The robot should now work with the remote control as it did out of the box.

Note to the Teacher

Note that if you have never downloaded anything onto your VEX microcontroller, you can skip this step.

VEX Kits and Accessories Needed

1. VEX Protobot Kit
2. Hardware and Metal Kit
3. Transmitter & Receiver Kit
4. VEX Microcontroller

Additional Materials Needed

1. Stopwatch
2. English ruler

On Completing the Lesson, Students will be Able to:

1. Build a robotic test bed
2. Identify the independent, dependent, and control variables in this investigation
3. Run the investigation using 3 different conditions
4. Collect data, record it on a data table, and graph the data
5. Convert between centimeters and inches
6. Apply and clarify various points of experimental procedure:
   a. Experimental hypothesis
   b. Measurement technique
   c. Multiple trials
   d. Systematic error
   e. Random error
7. Analyze data and draw conclusions
8. Extrapolate the new distance traveled based on prior testing
9. Write up a summary of lessons learned in the investigation

Description of the Investigation

In this investigation, students will begin with a modified squarebot using the default code and a radio. They will set up a course marked with tape at the start and finish positions for the robot to travel. They will measure the diameter of the wheels. One student will drive the robot and the other will time it. At the end of each test, students will record the time it took for the robot to travel from the beginning to the end in their data table. Students will repeat this procedure 5 times. After the data is collected, students will average their data and calculate average speed from the distance traveled divided by the average time. They will then change the diameter of the wheels and repeat the procedures, thereby testing all three conditions.

The investigation is designed so that the students use the following variables:

1. Independent variable - the size of the wheels on the robot
2. Dependent variable - the speed the robot travels from point A to point B
3. Control variable - distance traveled

Note to the Teacher

Procedures for Wheel Size Matters

Please note: if you have a programming kit and have downloaded any programs to your controller, you will need to download the default code before beginning this investigation. Select Build & Download/Download Default Code on the Easy C interface. (If you have not downloaded any programs, the default code is still on your Vex controller.)

1. Modify squarebot with the first (small) wheel condition

2. Prepare the testbed the robot will be tested on

3. Secure a watch to track time

4. Identify who will drive the robot and who will track time

5. Practice driving the robot and tracking time

6. Measure the diameters of the three wheel sizes

7. Record the diameters on the data table

8. Collect data:

- **a.** Set robot behind the start line
- **b.** Robot crosses start line--start timing
- **c.** Robot crosses finish line--end timing
- **d.** Record time in data table
- **e.** Repeat five times
- **f.** Average time of five trial runs
- **g.** Calculate average speed of the condition
- **h.** Plot Wheel Size vs. Speed for the condition.

9. Change to the second (medium) wheel condition for second trial

10. Estimate the speed of the second wheel based on its relative size.

11. Collect data for the second condition by repeating 8a-8h above.

12. Extrapolate the speed for the third (large) condition

13. Repeat 8a-8h for third condition

Standards Addressed

Science Standards

- Content Standard “A” Science as Inquiry
- Content Standard “B” Physical Science
- Content Standard “E” Science and Technology
- Unifying Concepts
  - Systems, Order, and Organization
  - Evidence, Models, Explanation
  - Constancy, Change, and Measurement
  - Evolution and Equilibrium

Math Standards

- Numbers and Operations
- Algebra

Note to the Teacher

Geometry

Measurement

Problem Solving

Reasoning and Proof

Communications

Connections

Technology Standards

The Nature of Technology Standards 1, 2, 3

Design 8, 9, 10

Abilities for a Technological World 12

The Designed World 16, 17

Math Versus Science

As students complete the investigations, they will begin to understand the relationship between mathematics and science. Mathematics is pure; when you plug numbers into equations, you will get the same result every time. Science, on the other hand, is dependent on multiple variables that may or may not be in control of the investigator. A good scientist will eliminate as many uncontrollable variables as possible so that they are able to analyze and measure the results of their investigation.

Experimental Error

There are many things that can cause your experimentally measured numbers to fall off-target from the predicted values. Here are a few:

- **Systematic error** is something in the experiment that always throws off the data in the exact same way. Some examples of systematic errors are a dead battery, improperly connected components, or a defective motor.
- **Random error** is caused by small factors that constantly change and affect the experimental results. In this experiment, random error may be caused by inconsistent starting points, imprecise measuring procedures, or a fluctuating battery level.
- **Friction** works to slow your robot. Robots with higher speeds not only encounter more friction from the ground, but in our case, they also have less torque due to their lower gear ratios. Less torque means that the robot is less able to push itself along, and will consequently suffer a greater speed loss.
- **Wheel Slippage** occurs at higher speeds or during acceleration, at which point wheels are more likely to slip relative to the ground. This results in a shorter distance being traveled. Often, wheels will slip unevenly on different sides of the robot, making the robot move along a curve rather than a straight line, which makes it difficult to measure how far it's gone.
- **Acceleration Time** is the amount of time the robot requires to reach its maximum speed. When calculating average speed, experiments must keep in mind that the robot needs time to accelerate to its actual top speed. With lower torque conditions, this time becomes significantly larger, and the average speed suffers.

Note to the Teacher

This investigation includes worksheets where students can capture data and write conclusions. The figures below are examples of graphical analysis of the data in Microsoft Excel.

Condition (Wheel Size)	TIME (seconds)						Avg Speed (in/sec)
	1	2	3	4	5	Average Time	
1 (small) Diameter = ________ in.	2.87	2.94	3.03	2.91	2.97	2.94	24.5
2 (medium) Diameter = ________ in.							
3 (large Diameter = ________ in.							

Extension Activities

Extension activity 1

Given a programming kit, write a program that has the robot travel a specific amount of time (three seconds) for each trial and then stop the motors. The time of the motors running is the constant in the investigation, the independent variable is the wheel size, and the dependent variable is the distance the robot travels.

Extension activity 2

This extension requires a line follower sensor and a bumper switch. Write a program that will record the amount of time it takes to get from one line to the next. Begin by presetting the timer to 0. When the bumper switch is hit, it then moves forward. When the line follower sensor "sees" the beginning of the first line, it will "start" the timer. It will then move forward until the sensor sees the beginning of the second line. At this point it will stop the timer. Reconnect the VEX controller to the computer to display the time of travel on the screen.

Distance is the constant in the investigation, the independent variable is the wheel size, and the dependent variable is the speed as calculated from distance and time.

Extension activity 3

Given a programming kit and an encoder write a program that travels a set number of encoder ticks and stops.

The number of rotations of the wheels is the constant in the investigation, the independent variable is the wheel size, and the dependent variable is the distance the robot travels (similar to Extension activity 1).

Extension activity 4

Draw a plot of Wheel Diameter (inches) vs. Speed (inches/second) based on the averages in the data table above.

Note to the Teacher

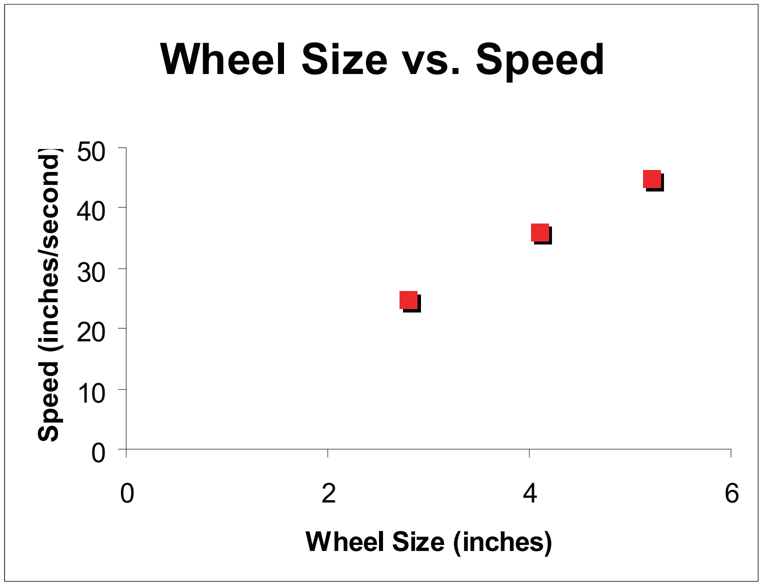


Figure 1: Typical Data from the Basic Investigation

Answer the following questions:

What is the hypothesis of this experiment?

A larger size wheel wiill reach a higher speed in a set distance.

Is this hypothesis supported by the data?

The hypothesis is clearly supported by the data. Larger wheels reach a higher speed than smaller wheels in a given distance.

Why did the robots reach different speeds when it used different wheel sizes?

A larger wheel has more circumference than a smaller wheel, which means that the robot will travel farther forward per turn of the wheel. You can think of the relationship as "unrolling" the circumference of the wheel onto the ground to get the distance traveled; a larger wheel would "unroll" over a longer distance per unit of time, and so goes faster.

Imagine the robots were placed on a different surface (i.e. carpet, table, floor, etc.). Would this change the speeds the robots reach? Why?

The robots may reach different speeds than they did in this investigation because different surfaces cause different amounts of wheel slippage. A smoother, glassy surface may cause the wheels to spin, thus reducing the average speed.

Extension Activity 5

In this enrichment activity, students measure the diameter of the wheel and calculate its circumference.

Extension Activity 6

In this activity students convert the circumference values to centimeters.

Answer the following questions:

Calculate the circumference of each wheel in inches. Convert the values to centimeters.

Circumference is found by multiplying diameter by pi (3.14):

2.75 in x 3.14 = 8.64 in

Inches can be converted to centimeters by multiplying by 2.54. Shown below are the conversions using the factor-label method.

Note to the Teacher

8.64 in x (2.54 cm / 1.00 in) = 21.1 cm

Extension Activity 7

In this enrichment activity, students plot the data, and are expected to predict values that would lie in between the known values. This is accomplished by interpolation, defined as a method of constructing new data points from a set of known data points. They can also extrapolate values. Extrapolation is a type of interpolation in which predictions are made *beyond* (above or below) the known set of values.

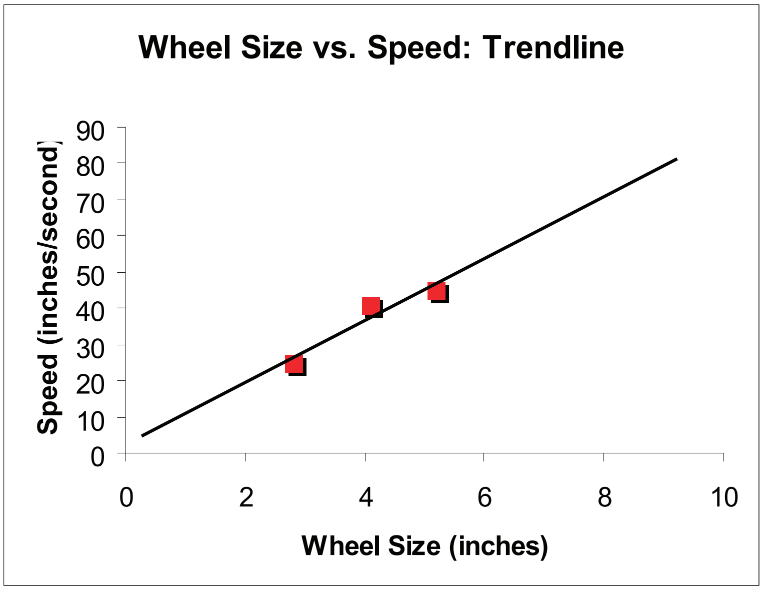


Figure 2: A typical plot for interpolation with a “best fit” line added, either through visual estimation or using an Excel “trendline” (NOTE THAT BEST FIT LINES OR TRENDLINES MAY NOT INCLUDE ALL DATA POINTS)

Answer the following questions:

Suppose you used a wheel that was about 4 inches in diameter. Based on Figure 2, about how fast might you expect the Squarebot to go?

The robot would go some speed between the Condition 2 speed and the Condition 3 speed. In our sample data shown above, that means it would be about 35 inches/second. Students determine this value by actually drawing a vertical line up from the 4 inch diameter to the line, then drawing a horizontal line over to the Y-axis.

Will the Squarebot in the example above always reach this speed? Why or why not?

No, it won’t always reach this exact speed; see “Systematic and Random Errors” for the various reasons.

Suppose you had a wheel that was even larger than the large, knobby tire (Condition 3), approximately 7 inches in diameter. About how fast might you expect the Squarebot to go?

The robot must go faster than the Condition 3 distance, with the estimated speed determined by the exact size of the wheel. A good estimate on this plot would be 65 inches/second. Students determine this value by drawing a vertical line up from the 7 inch diameter to the line, then drawing a horizontal line over to the Y-axis.

Will the Squarebot in the example above always go this distance? Why or why not?

*No, it will not. See the similar question for the Interpolation plot above.*principles to the lesson procedures.