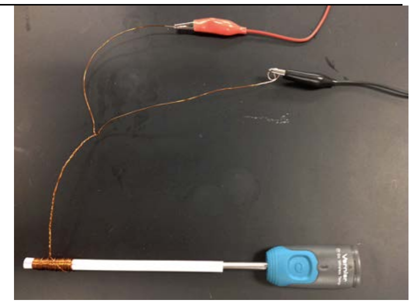
Building an Electric Heater

Science, Technology, Engineering and Math Objectives:



- Students will research science topics including:
  - Heat and temperature change
  - Wire resistance
  - Electrical heating power
  - Heating and cooling rate
- Students will engineer and build a simple electric heater that will warm an object).
- Students will use appropriate technology to evaluate their design, collaborate with colleagues and present their findings.
- Students will use a simulation to understand and model the effects of wire type, cross section and length on heating power.
- Students will use mathematical processes of:
  - Graphing
  - Linear equation modeling
  - Regression analysis
  - Data analysis

Vocabulary

- Resistivity
- Current
- Voltage
- Heating power
- Heating/cooling rate

About the Lesson

- While using TI-Nspire™ technology, this project based STEM activity will engage your students in the engineering design process:
  - Identify
  - Research
  - Design
  - Create
  - Evaluate
  - Communicate

Tech Tips:

- This activity includes screen captures taken from the TI-Nspire App for iPad. It could also be used with the TI-Nspire family of products including TI-Nspire handheld and software and a traditional wired Vernier temperature sensor. Slight variations to these directions may be required if using other technologies besides the iPad app.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials

Lesson Files:
Student Activity

- Build_an_Electric_Heater_Student.doc
- Build_an_Electric_Heater_Student.pdf
- Build_an_Electric_Heater.tns

Activity Materials Per Student Group

- Compatible TI Technologies: TI-Nspire™ Apps for iPad®
- Vernier™ Go Wireless® Temp sensor
- Drinking straw without paper jacket
- 2 meters of Magnet Wire 24 Gauge AWG Enameled Copper
- 6-Volt Super Heavy Duty Lantern Battery
- Knife Blade switch-single pole single throw (double throw if optional fan is used)
- Insulated alligator clip leads.
- 5volt brushless DC cooling fan 25mm x 25mm

Safety Tip: Make sure your students remove the paper wrapper from the drinking straw.

Safety Tip: Do not leave battery attached after experiment as heater may become too hot.

Safety Tip: Never use an electrical receptacle as a power source in this activity.

Discussion Points and Possible Answers

The Engineering Problem

Your Company designs and manufactures consumer electronics. Your project manager has tasked you with designing a new line of battery powered consumer appliances that will keep a hot drink, such as coffee or tea, warm for a long period of time. Your task is to design a small electric heating element for the new line of products and to verify your design with test data.

STEM Career

An electrical engineer is a person who generally deals with the study and application of electricity, electronics and electromagnetism. It is a branch of engineering that may involve the design, production and the operation of power utilities, automotive and consumer electronics.

Teacher Tip: Students may find it valuable to serve specific roles while they work in groups to complete these projects.

Career Roles

Some possible roles could include –

- **Project Manager** – This person ensures that all members of the team are meeting their deliverables. The project manager is the creator and manager of the schedule and ensures tasks are being completed on time.
- **Safety Facilitator** – This role ensures the area is clean and safe for the production of the project. For this specific project, this person may wish to actively observe that the materials are able to withstand heat being generated. They will need to keep a watchful eye over the electric heater and the data that is generated.
- **Engineer** – This individual is comfortable with making recommendations on the design of the project. They have researched the materials, supplies, and underlying mechanisms for the suggested design. They will create the design, likely digitally or on paper, before it is tested.
- **Builder** – The builder will actually follow the design of the project and put all of the pieces together. The builder will also discuss with the engineer and safety facilitator any changes necessary for the design.

1. **Identify:** State your engineering goal here. What are you trying to build? What does it need to accomplish? How will you evaluate how well it works?

   Answers will vary

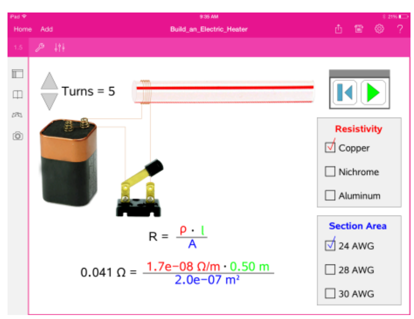
2. **Research:** Use appropriate internet resources to learn about your engineering goal. Your research may include building processes, constraints, potential problems, sources of error, materials, time limits, and scientific principles that apply to your design.

   Answers will vary

Make sure you pay close attention to the Background Information and the instructions that are included on page 1.3.

Use this information as you experiment with the simulation on page 1.4 in the document. Pay attention to the warning messages that may pop up during the simulation.

Check your understanding by answering the questions that follow the simulation in the document.



Teacher Tip: Page 1.11 in the document explains the equation for resistance to the students. Students are challenged with trying to solve a problem with known variables.

Use the equation: $r = (\rho \times l)/A$

where,

r = resistance (Ω); value is unknown

ρ = material resistivity (Ω/m); $1.68 \times 10^{-8}\ \Omega/m$

l = length of wire (m); $200\ cm$ or $2\ m$

d = diameter of wire (m); $.0511\ cm$ or $5.11 \times 10^{-4}\ m$

Use diameter to determine Cross Sectional Area (A) with the area of a circle formula, $A = \pi r^2$.

$\pi * (5.11 \times 10^{-4}\ m/2)^2 = 2.05 \times 10^{-7}\ m^2$

A = cross sectional area (m^2); $2.05 \times 10^{-7} m^2$

$$r = \frac{1.68 \times 10^{-8} \Omega/m \times 2m}{2.05 \times 10^{-7} m^2}$$

$$r = 0.1638\ \Omega$$

3. **Design/Prototype:** Once you have researched the engineering goal, create a plan for the building of your design. Your design may include drawings, labels, materials lists, cost lists, etc. The prototype may be a first-time attempt at building the final product to learn how to put it together. Share your design and prototype with others, listen to their suggestions and decide for yourself the very best design.

Answers will vary

a) Increasing the cross sectional area of a piece of wire will…

Answer: B. decrease the resistance

b) Increasing the resistivity of a piece of wire will…

Answer: A. increase the resistance

c) What is the best combination for building an electric heater

Answer: A. Long thin nichrome wire

d) A battery can't deliver much current. To reduce the current flow an engineer could…

Answer: C Both A and B would work

e) To increase current flow through the circuit, an engineer could…

Answer: D All of the above

4. **Create/Build:** Use your design and prototype experience to build your product to your specifications.

   Answers will vary

5. **Evaluate/Test:** Design an experiment that will help you to decide the best design to accomplish the engineering goal. You can use the Vernier Go Wireless™ Temp probe. On page 3.2 you will find data collection page for the Temp probe.

   Answers will vary

6. **Analyze:** Determine a method to analyze the collected temperature data that will help you to decide the best design. You might consider: change in temperature, best-fit linear regression, and exponential decay models

   Answers will vary

7. **Refine:** After you have built your design and tested it, think about what you like and do not like about the design. Show your product to your friends and family and listen carefully to their comments. Include the best suggestions from your customer feedback into your design and rebuild your deign to make it better!

   Answers will vary

Observations students should make during their experiment(s)

a) Describe the shape of your graph.

   Answer: Most students will likely see a graph that starts with a high slope but subtly decreases into a lower slope.

b) What was your starting temperature?

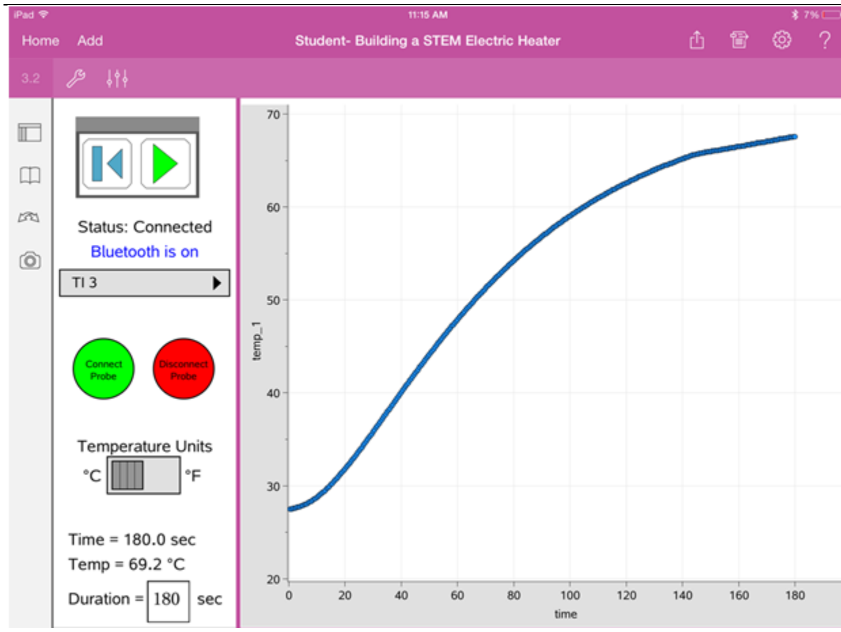
   Answers will vary

c) What was your final temperature?

   Answers will vary

d) As the slope of the graph changed, describe what was happening.

   Answer: The bigger the difference in temperature, the higher the rate of change of the graph. As the heat of the thermometer approaches the heat of the heater, the rate of change will decrease proportionally.



Possible results from project evaluation. The data shown was from a straw with 80 turns and was allowed to heat for 4 minutes, 30 seconds.
(done with Vernier DataQuest with a Vernier EasyTemp sensor and TI-Nspire CX Handheld)

8. **Present:** Prepare a brief presentation of your creation in a cloud-based collaborative environment such as Google Drive. Share your presentation with your teacher, family and friends.

   <u>**Answers will vary**</u>

Wrap-Up

Students will have the opportunities to try a different number of loops with the wire to see how length will influence resistance and heat production.

Assessment

- Students will answer questions to ensure they understand the relationships between cross sectional area, wire length, resistivity, and current flow in a conductor.